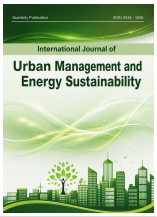
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Computational operationalization of architectural order: Bridging Alexander's living structure and Jencks' cosmogenic complexity through AI-enhanced urban morphogenesis

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ABSTRACT

Contemporary cities has produced fragmented and environmentally inefficient environments, while generative and artificial intelligence design tools are adopted without a theoretical basis for judging whether their forms are coherent and culturally appropriate. Christopher Alexander's living order and Charles Jencks' cosmogenic complexity offer competing answers, yet how far each can be translated into computable criteria, and how either relates to traditional Iranian architecture, remains unclear. This study compares the two paradigms, assesses their computational operationalization, examines their congruence with traditional Iranian architecture and develops an integrated computational framework. A systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, Web of Science and Google Scholar. Of 358 identified records, 40 sources were analysed through directed qualitative content analysis, and a six-dimension ordinal rubric rated computational maturity. Alexander's living order scored 4–5 on all six dimensions, being operationalized through wholeness metrics, graph-theoretic models, harmony-seeking algorithms and language-model-based evaluation, whereas Jencks' cosmogenic complexity scored only 1–2 and remains largely rhetorical. Five convergences and five divergences show the paradigms to be complementary. Traditional Iranian architecture expresses seven of Alexander's properties through the courtyard, neighbourhood hierarchy, arcades, wind towers and girih geometry, and is partially congruent with Jencks' fractal complexity. A five-layer framework of wholeness, complexity, cultural contextualization, performance and adaptive management is proposed to integrate both paradigms. Future studies should develop and validate computable complexity metrics, test the framework through demonstration projects and post-occupancy evaluation in historic Iranian neighbourhoods, and extend it to other cultural traditions

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INTRODUCTION

Order is one of the most fundamental concepts in human thought, permeating philosophy, art and architecture. The Arabic root "Naẓm" signifies "gathering, assembling, threading pearls upon a string" a metaphor that captures the essence of bringing disparate elements into coherent relationship (Ibn Manẓūr, 2004). In architectural discourse, order transcends mere geometric arrangement to encompass deeper questions of meaning, experience, beauty and the relationship between built form and natural processes. From Vitruvius' classical proportional systems to contemporary computational morphogenesis, architects have continuously sought to understand and manifest order as both aesthetic principle and organizational logic (Vitruvius, 1914). The late twentieth and early twenty-first centuries produced two influential yet divergent frameworks for understanding architectural order. Christopher Alexander's The Nature of Order proposes that living structure emerges through incremental, harmony-seeking transformations guided by fifteen fundamental properties a vision grounded in phenomenological experience, pattern languages and organic growth (Alexander, 2002; Alexander, 1979). Charles Jencks' The Architecture of the Jumping Universe, conversely, embraces complexity science, chaos theory, fractals and cosmological metaphors, arguing that architecture should reflect the universe's self-organizing, nonlinear and emergent character (Jencks, 1997). Recent developments in computational urban science, artificial intelligence (AI) and algorithmic design have transformed how architectural theory translates into practice. Between 2024 and 2026, Alexander's qualitative concepts have been systematically operationalized through measurable metrics, graph-theoretic models and AI-driven evaluation tools (Jiang, 2024; Mehaffy et al., 2025; Li et al., 2025). This computational turn enables empirical interrogation of Alexander's claims about wholeness and living structure while providing practical design-support systems. In contrast, Jencks' cosmogenic architecture despite its theoretical richness and alignment with complexity science has not generated a comparable computational research program. A further gap concerns the relationship between these Western frameworks and non-Western traditions. Traditional Iranian architecture embodies profound attitudes toward nature, divine order, hierarchical spatial organization and pattern-based design that resonate with both Alexander's and Jencks' concerns, yet through distinct cultural and theological lenses (Nasr, 1996). Understanding these connections offers pathways for culturally grounded computational design.

The problem addressed by this study is both practical and theoretical. In practice, rapid and standardized urbanization has produced what many scholars describe as a crisis of architectural order: fragmented urban fabrics, repetitive and placeless buildings, weakened social cohesion and environmentally inefficient settlements that break with the climatic and cultural intelligence of traditional cities (Salingaros, 2005; Batty, 2013; Jiang, 2024). In many Iranian cities, this crisis is reflected in the erosion of historic mahalleh neighbourhoods and courtyard housing in favour of generic building types. At the same time, generative and AI-based design tools are spreading rapidly in architectural practice (Li et al., 2025), yet they are usually steered by narrow performance or visual criteria rather than by an explicit theory of what makes an environment coherent, living and culturally meaningful. Without such a theory, computation risks accelerating rather than resolving the crisis. Alexander and Jencks offer two of the most developed answers to the question of architectural order, but their relative readiness for computational use has never been systematically compared, and their relevance to non-Western traditions has not been examined in a structured way. This gap limits the ability of researchers, designers and policy-makers to select, combine and test theories of order in AI-enhanced urban design.

Historical theories of order in architecture

The concept of order in architecture has evolved through distinct historical phases, each reflecting prevailing cosmological, philosophical and scientific worldviews (Tab. 1). This trajectory reveals an enduring tension between transcendent conceptions of order eternal principles imposed upon matter and immanent conceptions, in which order emerges from within natural processes. Alexander and Jencks represent contemporary manifestations of this ancient dialectic, though both favour immanent, process-based understandings (Plato, 1870; Bettencourt, 2013).

Table 1: Historical theories of order in architecture

Theorist / school	Conception of order
Pythagoras	Order from numerical ratios and harmonic proportions; the cosmos is fundamentally mathematical
Plato	Order reflects eternal, transcendent Forms; the Demiurge imposes geometric order on primordial chaos
Aristotle	Order is immanent in nature through teleological processes; form actualizes potential in matter
Vitruvius	Architectural order derives from proportional systems mirroring the human body and cosmos
C. Alexander	Living order emerges through incremental, harmony-seeking transformations guided by fifteen properties
C. Jencks	Cosmogenic order arises from self-organization, nonlinear dynamics, fractals and complexity science

Alexander's living order

Between 2024 and 2026, a notable transformation occurred in how Alexander's theories are understood and applied: what began as qualitative, phenomenological observation evolved into a rigorous computational program with measurable metrics, algorithmic implementations and AI-driven evaluation. A central result is the formalization of "livingness" (L) as a function of structural complexity (S) and hierarchical depth (H), $L = S \times H$, capturing the insight that living structure requires both differentiation (many distinct centers) and integration (coherent hierarchical organization) (Jiang, 2019). Graph-theoretic representations, in which spatial elements become nodes and relationships become edges, allow centrality measures to quantify the strength of centers and clustering algorithms to identify nested scales, enabling objective comparison of configurations and prediction of which interventions most enhance wholeness (Jiang, 2016; Mehaffy et al., 2025). Alexander argues that every region of space has a measurable degree of life or wholeness, determined by the strength and coherence of its centers and their relationships (Alexander, 2002). Wholeness is an emergent quality arising from recursive, nested structures, and design should proceed by strengthening existing centers and creating new ones through "structure-preserving transformations." His fifteen fundamental properties levels of scale, strong centers, boundaries, alternating repetition, positive space, good shape, local symmetries, deep interlock and ambiguity, contrast, gradients, roughness, echoes, the void, simplicity and inner calm, and not-separateness describe recurring patterns in natural and traditional built environments (Alexander, 1964; Alexander et al., 1977). Seamon (2019) interprets the theory as a tetrad of ontological, phenomenological, generative and practical dimensions, integrating metaphysics, psychology and method into a unified framework.

Jencks' cosmogenic complexity

Building on his earlier semiotic critique of mod-

ernism (Jencks, 1977), Jencks embraces complexity science as both explanatory framework and aesthetic inspiration, arguing that architecture should reflect a universe understood as a self-organizing, far-from-equilibrium system characterized by feedback loops, bifurcations and emergence (Jencks, 1997). Drawing on deterministic chaos (Lorenz, 1963), fractal geometry (Mandelbrot, 1982), dissipative structures (Prigogine and Stengers, 1984) and autocatalytic networks (Kauffman, 1993), he proposes that architectural form should embody fractal self-similarity, nonlinear spatial sequences and emergent novelty. His "cosmic jumps" denote phase transitions at which quantitative change triggers qualitative transformation. Architecturally, these ideas manifest as fractal facades with detail at multiple scales, nonlinear circulation that offers multiple routes and ambiguous boundaries, computationally generated emergent form, and semiotically rich buildings that invite multiple readings. Critically, Jencks rejects timeless, universal order in favour of historical contingency and cultural specificity a postmodern sensibility that distinguishes his project from Alexander's search for universal patterns.

Methodological divergence: pattern language versus complexity modelling

The methodological implications of these philosophical differences are profound and largely explain the operationalization gap documented in the Results and discussion section. Alexander's pattern language identifies recurring, nameable solutions to design problems that have proven effective across diverse contexts; patterns are organized hierarchically from regional planning to building detail, and each pattern specifies a problem, its context, a solution and its relationships to other patterns (Alexander et al., 1977). This method is generative and participatory, and because patterns are discrete and relational they translate naturally into graph-theoretic models in which patterns become nodes and relationships become edges (Dawes and Ostwald, 2018). Jencks, by contrast, offers no systematic design methodology comparable to the pattern language; his approach is analytical and critical rather than generative, interpreting existing buildings as embodiments of complexity principles rather than prescribing step-by-step design processes. This asymmetry discrete, relational and procedural versus continuous, mathematical and interpretive is the central reason Alexander's work has proven more amenable to computation (Gero and Kannengiesser, 2004).

Accordingly, this study addresses four research questions (RQs): (RQ1) How do Alexander's living order and Jencks' cosmogenic complexity compare across epistemological, methodological and phenomenological dimensions? (RQ2) To what extent has each paradigm been computationally operationalized in recent scholarship (2016–2026)? (RQ3) In what ways do these paradigms converge with traditional Iranian architectural principles? (RQ4) How can the two paradigms be integrated into a coherent computational framework for contemporary practice? To answer these questions rigorously, the study adopts a systematic-review research design rather than a narrative review, making its search, selection and synthesis procedures explicit and reproducible. The study makes four contributions. Theoretically, it provides the most comprehensive comparative analysis to date of the two paradigms across epistemological, methodological, phenomenological and computational dimensions. Methodologically, it introduces a transparent, reproducible computational-maturity assessment that can be applied to other theories of architectural order. Culturally, it establishes a structured congruence between pattern-based order and traditional Iranian architecture, grounding computation in heritage. Practically, it proposes an integrated, layered framework and research agenda that translate theory into actionable design processes. In doing so, the paper responds to a widely noted need to move architectural theory from philosophical speculation toward testable, reproducible and culturally responsive

scientific inquiry (Mehaffy et al., 2025; Jiang, 2024). Accordingly, the aim of the current study is to compare the two paradigms, assess their computational operationalization, examine their congruence with traditional Iranian architecture and develop an integrated computational framework for culturally grounded, AI-enhanced urban morphogenesis. This study was carried out as a desk-based systematic review at University/institute name, City, Iran, in 2025–2026; the database search was last updated in Month 2026.

MATERIALS AND METHODS

This study is, by purpose, fundamental and, by the nature of its data, qualitative. It employs a systematic review combined with directed qualitative content analysis and conceptual-framework synthesis. This design is appropriate because the research questions concern the state, structure and integration of a body of theoretical and computational knowledge rather than a primary empirical phenomenon; the scholarly literature itself constitutes the unit of analysis. Systematic reviews and conceptual syntheses are well-established, high-quality research designs in architecture and urban science. The review followed a three-stage protocol. First, a systematic identification and screening of sources was carried out in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021). Second, the included sources were analysed through directed qualitative content analysis, in which an initial coding scheme derived from theory is applied and refined against the data (Hsieh and Shannon, 2005). Third, the resulting categories were integrated into a conceptual framework through interpretive synthesis. All three stages were documented to ensure transparency and reproducibility. Three databases Scopus, Web of Science and Google Scholar were searched for the period 1960–2026, combining terms for the two paradigms, for computation and for cultural context (Tab. 2). The search was complemented by backward and forward citation tracking of seminal works. As summarized in the PRISMA flow diagram (Fig. 1), 312 records were identified through database searching and 46 through hand-searching; after removal of duplicates, 274 records were screened on title and abstract, 106 full texts were assessed for eligibility, and 40 sources were retained for the qualitative synthesis. The retained corpus deliberately balances foundational theory, recent computational advances (2020–2026) and sources on traditional Iranian architecture.

Table 2: Search strategy and eligibility criteria

Element	Specification
Databases	Scopus; Web of Science; Google Scholar (+ citation tracking)
Time span	1960–2026 (foundational to state-of-the-art)
Search terms	(“living structure” OR “wholeness” OR “pattern language” OR “Christopher Alexander”) AND (“cosmogenic” OR “complexity” OR “fractal” OR “Jencks”) AND (“computational” OR “algorithmic” OR “AI” OR “morphogenesis”); plus “Iranian architecture”, “girih”, “courtyard”
Inclusion	Peer-reviewed articles, scholarly books and conference papers addressing architectural/urban order, its computation, or Iranian pattern-based design
Exclusion	Non-scholarly items; works without theoretical or computational relevance; duplicative scope
Analysis	Directed qualitative content analysis; conceptual-framework synthesis

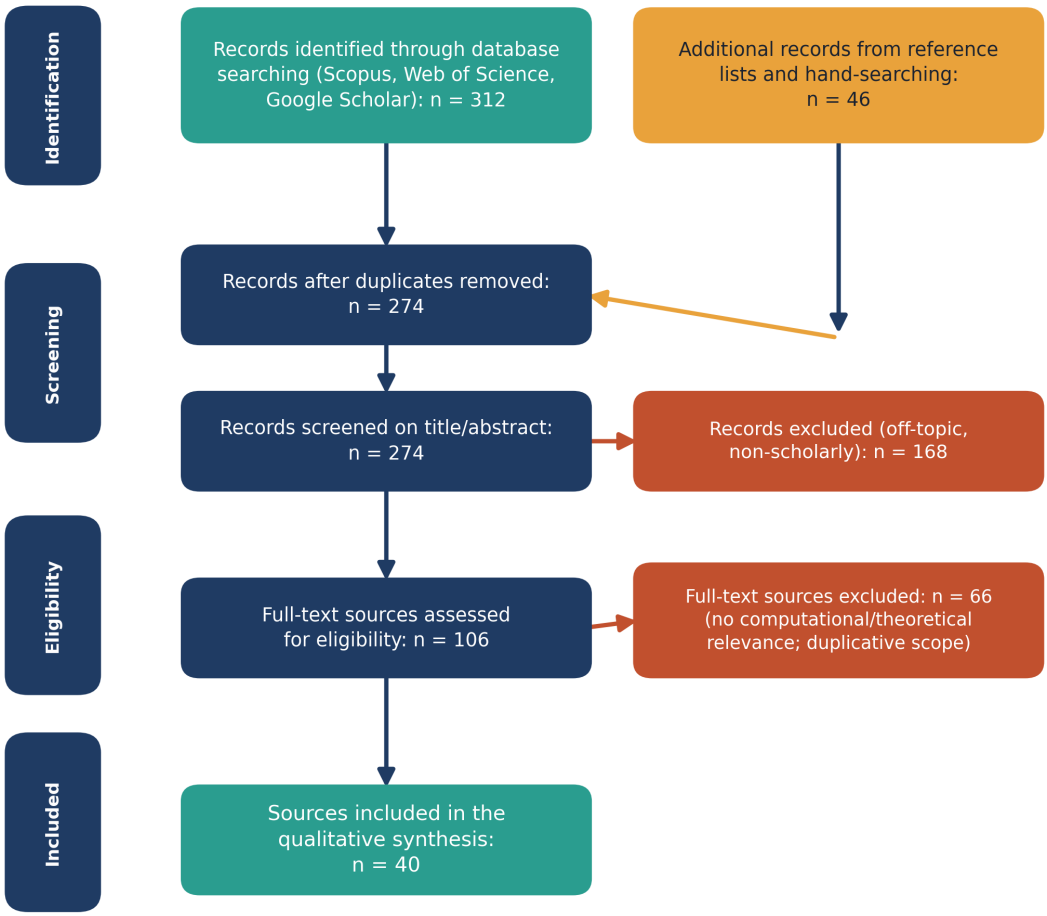


Figure 1: PRISMA 2020 flow of the systematic identification and screening of sources

For each included source, data were extracted on paradigm addressed, epistemological and methodological stance, computational technique (if any), reported evidence, and cultural context. Codes were organized under theory-driven categories ontology, epistemology, methodology, temporal character, computational status and cultural stance and compared across the two paradigms using the constant-comparison logic of content analysis (Hsieh and Shannon, 2005). A computational-maturity rubric (see the computational maturity assessment in the Results and discussion section) was then applied to rate, on an ordinal scale, the degree to which each paradigm has been formalized, implemented, AI-integrated, empirically validated, embedded in design tools and expressed through quantitative metrics. These ratings are an analytic synthesis of documented evidence, not primary empirical measurements.

FINDINGS AND DISCUSSION

Systematic comparison of the two paradigms

Content analysis of the corpus yields a structured comparison across the core dimensions of architectural theory (Tab. 3). Five convergences and five divergences were identified consistently across sources. The convergences are: a shared critique of mechanistic modernism; a grounding of theory in observations of nature; a rejection of arbitrary formalism in favour of form that serves life or reflects scientific understanding; an em-

phasis on multiscalar order in which structure manifests at every level; and a prioritization of generative process over fixed formal outcomes. The divergences are equally significant: universalism versus pluralism; continuity versus rupture; harmony versus productive tension; phenomenology versus science; and implicit spirituality versus resolute secularism. Rather than irreconcilable opposites, the two frameworks are better understood as complementary: Alexander supplies a phenomenological, experiential and generative account, while Jencks supplies a scientific, analytical and critical one. This complementarity is the conceptual foundation for the integrated framework developed in the final subsection of the Results and discussion.

Table 3: Systematic comparison of Alexander's and Jencks' paradigms

Dimension	Alexander: living order	Jencks: cosmogenic complexity
Nature of order	Organic, incremental, harmony-seeking, timeless	Dynamic, nonlinear, emergent, historically contingent
Epistemology	Phenomenological observation, intuition	Scientific modelling, mathematical formalization
Methodology	Pattern language, structure-preserving transformation	Conceptual frameworks, metaphorical inspiration, critique
Aesthetic criterion	Deep beauty, coherence, feeling of life	Sublime complexity, fractal self-similarity, cognitive challenge
Temporal orientation	Evolutionary, gradual adaptation	Revolutionary, punctuated equilibrium, "cosmic jumps"
Cultural stance	Universalist: patterns transcend cultures	Pluralist: order is culturally and historically specific
Computational status	Highly operationalized (graph models, AI, metrics)	Minimally operationalized (scattered, implicit)

Computational maturity assessment

To answer RQ2, each paradigm was rated on an ordinal maturity scale (0 = absent to 5 = mature) across six capability dimensions, drawing on documented evidence from the corpus (Tab. 4). Alexander's living order scores highly across all dimensions: wholeness has been expressed as calculable functions of structural complexity and hierarchical depth (Jiang, 2019); graph-theoretic and complex-network models quantify the strength of centers (Jiang, 2016; Dawes and Ostwald, 2018); harmony-seeking rules have been translated into executable, agent-based algorithms (Hoverd et al., 2010); large language model (LLM) evaluators score artifacts for Alexander's properties (Tanaka et al., 2026; Li et al., 2025); and quantitative wholeness measures have been correlated with user satisfaction and environmental performance (Mehaffy et al., 2025; Rofè, 2023). Jencks' cosmogenic complexity, by contrast, scores low: although complexity and fractal metrics exist in cognate work (Ostwald, 2001; Lee and Ostwald, 2023; Lee and Ostwald, 2024), they are rarely linked explicitly to his architectural program, and no systematic design methodology comparable to the pattern language has emerged.

The asymmetry has a clear explanation. Alexander's fifteen properties are discrete, nameable and relational, which makes them amenable to graph representation, measurement and optimization; his pattern language is itself a generative, rule-based method (Dawes and Ostwald, 2024). Jencks' principles fractals, strange attractors, self-organization are continuous, mathematical and metaphorical, and their archi-

Table 4: Computational maturity assessment matrix (ordinal rating 0–5)

Capability dimension	Alexander	Jencks	Illustrative evidence
Mathematical formalization	5	2	Livingness L = S × H; complex-network wholeness (Jiang, 2016)
Algorithmic implementation	5	1	Harmony-seeking agent rules (Hoverd et al., 2010)
AI-driven evaluation	4	1	LLM-based property scoring (Tanaka et al., 2026)
Empirical validation	4	1	Wholeness–satisfaction correlations (Rofè, 2023)
Design-support tools	5	1	Generative pattern operators (Li et al., 2025)
Quantitative metrics	5	2	Fractal dimension and entropy of facades (Lee and Ostwald, 2024)
Mean score	4.7	1.3	Arithmetic mean of the six dimensions

tectural application remains interpretive rather than procedural. Contemporary parametric and generative practice (Razzaghmanesh and Gürer, 2026) implicitly realizes aspects of Jencks' vision, but rarely cites him directly, underscoring the operationalization gap. The AI-driven strand of this operationalization is especially consequential. Recent systems use large-language and vision models to score images of buildings and urban spaces for the presence and strength of Alexander's properties, aggregating the results into overall wholeness ratings and comparing designs or iterations (Tanaka et al., 2026). Early evidence suggests that such evaluations correlate reasonably with expert human judgment, although subtle phenomenological qualities remain difficult to capture; the principal advantage is scalability, since thousands of designs can be assessed rapidly to support diagnostic, generative, educational and research applications (Li et al., 2025). Harmony-seeking algorithms complement these evaluators by treating design as a search for configurations that maximize wholeness: multiple agents propose modifications, assess their effect on graph-theoretic centrality and coherence, and accept changes that strengthen centers a distributed, bottom-up process that mirrors Alexander's vision of organic growth (Hoverd et al., 2010; Rofè, 2023). The absence of any comparable toolchain for Jencks' complexity is the clearest expression of the maturity gap and the strongest motivation for the research agenda proposed below.

Congruence with traditional Iranian architecture

Traditional Iranian architecture embodies principles that resonate strongly with Alexander's pattern-based living order, yet emerge from distinct theological and climatic contexts (Nasr, 1996). As Table 5 and Figure 2 show, the courtyard (hayāt) exemplifies Alexander's strong center; the city–mahalleh–house progression realizes nested levels of scale; arcades (revāq), wind towers (bādgir) and reflecting pools function as boundaries, gradients and the void; and girih geometry expresses good shape and local symmetries. Incremental, climate-adaptive growth over generations parallels structure-preserving transformation. The congruence with Jencks is partial: Iranian girih patterns exhibit fractal-like self-similarity and mathematical sophistication that resonate with complexity science (Razzaghmanesh and Gürer, 2026), and the cumulative effect of many small decisions produced complex, self-organized urban fabrics.(Tab. 5 and Fig. 2)

Table 5: Congruence between Alexander's properties and traditional Iranian architecture

Alexander's property	Iranian architectural expression
Strong center	Courtyard (hayāt) as climatic, social and symbolic focus
Levels of scale	Nested hierarchy: city → mahalleh → house → room
Boundaries / gradients	Arcades (revāq), transitional thresholds, light-to-shade sequences
Good shape / local symmetries	Girih geometry, proportional systems, sacred geometry

The void / positive space	Empty courtyard shaped as deliberately as solid mass
Structure-preserving growth	Incremental, climate-adaptive adaptation over generations
Not-separateness	Architecture as microcosm; connection to larger wholes

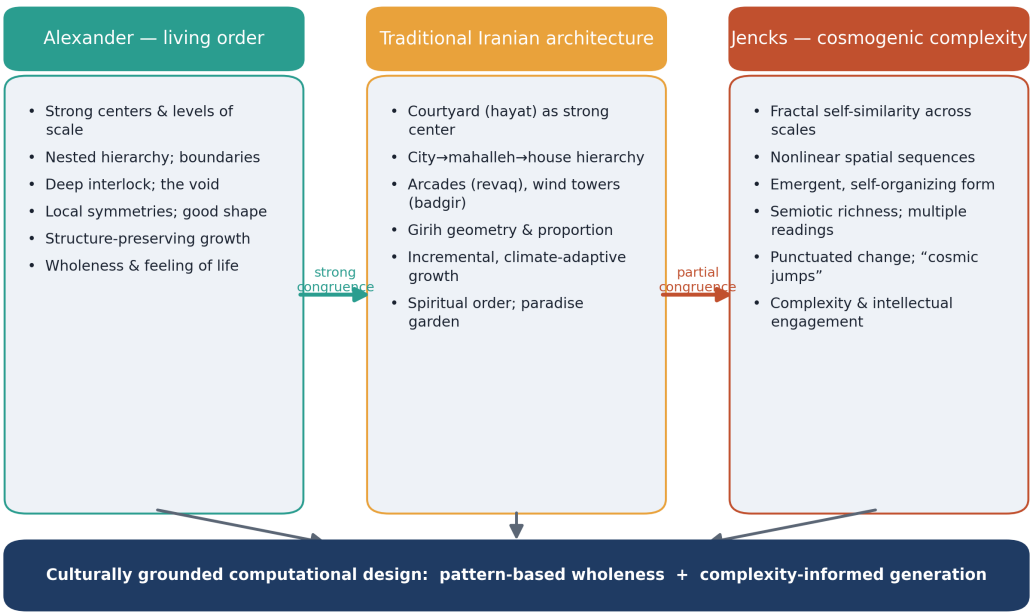


Figure 2: Thematic congruence map linking living order, cosmogenic complexity and traditional Iranian architecture

Traditional Iranian architecture can be read as an implicit pattern language, transmitted through craft traditions, apprenticeship and cultural continuity rather than written documentation. Its patterns operate across three scales (Tab. 6). At the urban scale, organic street networks provide shade and wind protection, self-contained mahalleh neighbourhoods organize around mosque, bazaar and bathhouse, and the linear bazaar acts as an activity spine close analogues of Alexander's "Network of Paths and Cars," "Identifiable Neighbourhood" and "Promenade." At the building scale, the inward-facing courtyard house, wind towers (bādgir) and reflecting pools correspond to "Positive Outdoor Space," "Natural Ventilation" and "Still Water." At the detail scale, muqarnas, lattice screens (shabakeh) and tile work embody "Ornament," "Filtered Light" and "Contrast." These patterns exhibit precisely the interconnectedness, scalability, adaptability and cultural embeddedness that Alexander identifies in successful vernacular traditions, and their geometric sophistication provides a bridge to complexity-based analysis (Lee and Ostwald, 2024).

Table 6: Traditional Iranian patterns across three scales and their Alexandrian analogues

Scale	Iranian pattern	Alexandrian analogue
Urban	Organic shaded street networks; mahalleh units; bazaar spine	Network of Paths and Cars; Identifiable Neighbourhood; Promenade
Building	Courtyard house; wind tower (bādgir); reflecting pool	Positive Outdoor Space; Natural Ventilation; Still Water

Detail	Muqarnas; lattice screen (shabakeh); tile work / girih	Ornament; Filtered Light; Contrast / Deep Reveals

The relationship with Jencks' cosmogenic architecture reveals both tensions and possibilities. Tensions arise around continuity versus rupture, harmony versus tension, and the sacred versus the secular: Iranian tradition emphasizes continuity, harmony and theological meaning, whereas Jencks celebrates discontinuity, productive tension and secular cosmology. Yet real possibilities exist: Iranian girih tiles exhibit fractal-like self-similarity and mathematical sophistication that resonate with complexity science; the aggregate of countless small decisions produced self-organized urban fabrics; and Islamic geometric patterns support multiple readings and symbolic meanings consistent with Jencks' emphasis on semiotic richness. Computationally formalizing these patterns therefore offers an alternative to both uncritical historicism and cultural erasure, enabling contemporary architecture that is simultaneously innovative and culturally rooted (Razzaghmanesh and Gürer, 2026; Salingaros, 2005).

An integrated five-layer computational framework

Synthesizing the preceding findings, an integrated computational framework is proposed that treats living order and cosmogenic complexity as complementary layers rather than competing paradigms (Tab. 7). Layer 1 establishes a wholeness foundation using Alexander's centers, hierarchy and pattern language, optimized through wholeness metrics. Layer 2 introduces complexity enhancement through fractal detail and generative emergence, measured by fractal dimension and entropy (Lee and Ostwald, 2023). Layer 3 provides cultural contextualization by encoding traditional patterns such as Iranian girih as computational operators (Razzaghmanesh and Gürer, 2026). Layer 4 adds performance optimization across environmental, structural and social criteria, and Layer 5 enables adaptive management through monitoring, repair and incremental improvement. The layers are reconciled through multi-objective optimization that balances wholeness, complexity, cultural coherence, performance and adaptability.

Table 7: The five-layer integrated framework: objectives and computational tools

Layer	Primary objective	Computational tools
1. Wholeness foundation	Strong centers, nested hierarchy, human-centered patterns	Graph-theoretic wholeness models; pattern operators
2. Complexity enhancement	Fractal richness and emergent form across scales	Cellular automata; agent-based and generative models
3. Cultural contextualization	Encode and measure local/traditional coherence	Digitized pattern libraries; culturally-constrained rules
4. Performance optimization	Environmental, structural, economic and social performance	Environmental simulation; multi-objective optimization
5. Adaptive management	Incremental change, monitoring and adaptive reuse	Post-occupancy dashboards; feedback and digital twins

Realizing the framework requires computational tools of five kinds: multi-objective optimizers that explore trade-offs among wholeness, complexity, cultural coherence and performance using Pareto methods; hybrid generative processes that combine pattern-based operators with complexity-informed models such as cellular automata and agent-based systems under constraint satisfaction; multi-scale integrators that coordinate decisions from region to detail; evaluation dashboards that report wholeness scores, complexity metrics, cultural alignment and per-

formance indicators in real time; and participatory interfaces that allow non-expert stakeholders to explore alternatives, express preferences and co-create solutions (Li et al., 2025; Tanaka et al., 2026). The framework's potential can be illustrated through three application scenarios. In the urban regeneration of a historic Iranian neighbourhood, Layer 1 would strengthen existing courtyard structures and repair street networks using Iranian patterns, Layer 2 would introduce contemporary interpretations of traditional geometric patterns, Layer 3 would engage the community in identifying valued patterns, Layer 4 would integrate passive-cooling strategies and accessibility, and Layer 5 would establish an incremental improvement process with continuous participation. In a contemporary university campus, the layers would create strong centers and legible hierarchies for learning, use generative algorithms for intellectually engaging form, incorporate regional traditions, optimize daylight and flexibility, and design for future reconfiguration. In a sustainable eco-district, they would create walkable, human-scale neighbourhoods, use self-organizing systems for infrastructure, engage future residents in co-design, maximize renewable energy and biodiversity, and enable incremental densification. In each case, the five layers operate together rather than sequentially, demonstrating how living order and cosmogenic complexity can be combined in practice.

Implications for theory, practice, pedagogy and policy

The computational operationalization of Alexander's living order and the latent formalizability of Jencks' complexity raise fundamental epistemological questions about how architectural quality is validated. Traditionally assessed through expert judgment and user surveys, quality can now be complemented by calculable, comparable and optimizable criteria (Jiang, 2024; Dawes and Ostwald, 2024). This does not eliminate judgment but adds evidence: Alexander's phenomenological insights can be empirically tested through correlation studies, and Jencks' claims could be examined through cognitive-science research. The appropriate stance is methodological pluralism using quantitative metrics as tools within broader processes that retain space for intuition, cultural knowledge and ethical deliberation. For practice, the framework suggests evolving professional roles. The architect becomes a curator of generative processes defining parameters, constraints and evaluation criteria while allowing algorithms to explore the design space and a facilitator who helps communities articulate values and weigh alternatives. The architect is also a researcher, engaging with post-occupancy data and contributing to cumulative knowledge; a synthesizer who integrates wholeness, complexity, culture and performance across disciplines; and a steward of incremental, adaptive environments rather than a one-time author of finished objects. These roles require new competencies in computational thinking, communication and ethical deliberation, but they extend rather than replace the designer's creative judgment (Gero and Kannengiesser, 2004). For pedagogy, the framework implies cultivating several literacies simultaneously: pattern literacy, to recognize and apply both universal and culturally specific patterns; computational fluency, for generative modelling, simulation and data analysis; complexity-science foundations, for understanding self-organization and emergence; phenomenological sensitivity, developed through drawing, model-making and site experience; cultural competence, through the study of vernacular traditions; and ethical reflection on whose values are embedded in optimization criteria. Reported experiences of teaching Alexander's The Nature of Order confirm both its transformative potential and the practical difficulty of applying it without computational support, underscoring the value of the tools surveyed here (Rofè, 2024; Zinovieva, 2025). For policy, performance-based codes and, potentially, wholeness or complexity standards could reward evidence-based, incremental development, while regulatory safeguards address

algorithmic transparency, participatory requirements and the risk that standardization erodes diversity. The framework also has sustainability implications. Alexander's living order supports sustainability through material efficiency, longevity, adaptability and human-scale, socially cohesive environments, echoing the health and well-being benefits documented for pattern- and nature-based design (Zhong et al., 2022). Jencks' complexity contributes adaptive capacity, resilience and biomimetic innovation. Integrating both pattern-based passive strategies with complexity-informed, computationally optimized active systems offers a route to environments that are simultaneously livable, resilient and culturally rooted (Salingaros, 2005; Batty, 2013). Important cautions accompany these opportunities. Quantitative metrics risk reductionism (oversimplifying rich phenomenological experience), gaming (optimizing proxies without improving actual quality), cultural bias (embedding particular aesthetic preferences in ostensibly objective measures) and mechanization (replacing human judgment with algorithmic decision-making). The integrated framework therefore positions computation as a means, not an end, and foregrounds cultural preservation: rather than freezing historic forms, it identifies underlying patterns and principles that can be adapted for contemporary contexts, and it uses computational tools to document and formalize traditional knowledge digital pattern libraries, wholeness assessments of historic buildings, and generative models of traditional design processes so that heritage is honoured without pastiche (Zinovieva, 2025; Zhong et al., 2022). These findings are consistent with the broader configurational tradition in architecture and urban science, which treats spatial structure as analysable and measurable (Hillier and Hanson, 1984; Hillier, 2007), with complexity-based accounts of scaling and self-organization in cities (Bettencourt, 2013; Batty, 2013), and with design-theoretic accounts of how problem framing shapes generated form (Gero and Kannengiesser, 2004). Together they situate the proposed framework within an established, methodologically plural science of the built environment.

Taken together, these implications point toward a new paradigm for architectural theory and practice that transcends the modernism–postmodernism divide by acknowledging both cross-cultural patterns and contextual specificity; bridges science and phenomenology by treating scientific modelling and lived experience as equally valid sources of knowledge; balances stability and change by providing mechanisms for preserving valuable structure while enabling innovation; democratizes design through accessible patterns and computational tools; supports sustainability by aligning practice with ecological principles and long-term resilience; and enables evidence-based practice while respecting qualitative dimensions. This paradigm does not resolve every tension between Alexander and Jencks, but it reframes their opposition as a productive, designable spectrum rather than a binary choice.

RESULTS AND CONCLUSION

This study set out to compare Alexander's living order and Jencks' cosmogenic complexity, to assess their computational operationalization, to examine their congruence with traditional Iranian architecture, and to integrate them into a coherent framework. Using a PRISMA-guided systematic review and directed content analysis of forty sources, four principal findings emerged. First, there is a pronounced computational-maturity asymmetry: Alexander's living order has achieved substantial operationalization, with ordinal scores of 4–5 on all six capability dimensions (mean 4.7), whereas Jencks' cosmogenic architecture remains largely theoretical, scoring only 1–2 (mean 1.3), with its weakest dimensions being algorithmic implementation, AI-driven evaluation, empirical validation and design-support tools. Second, the two paradigms are complementary rather than competing phenomenological and experiential on one side, scientific and critical on the other. Third, traditional Iranian architecture is strongly congruent with Alexan-

der's pattern-based order and partially congruent with Jencks' complexity, offering a basis for culturally grounded computational design: seven of Alexander's properties find direct expression in the courtyard, the city–mahalleh–house hierarchy, arcades, wind towers, reflecting pools and girih geometry. Fourth, a five-layer framework wholeness, complexity, cultural contextualization, performance and adaptive management can integrate the two visions in both research and practice. The theoretical contribution of the paper is threefold: the most comprehensive comparative and computational assessment to date of these paradigms; a reproducible computational-maturity assessment; and a novel, culturally grounded integrative framework. Practically, the framework points toward evidence-based design, AI-assisted design support, participatory processes and incremental, structure-preserving development. For Iranian cities in particular, the findings suggest that the regeneration of historic neighbourhoods and the design of new districts need not choose between imported generic models and nostalgic imitation: encoding courtyard, mahalleh and girih patterns as computational operators allows heritage to inform AI-assisted design while remaining open to contemporary needs. For designers and municipal decision-makers, the maturity assessment also indicates which theoretical tools are ready for use now, namely wholeness metrics and pattern-based generative operators, and which still require development before they can responsibly guide practice.

Several limitations should be acknowledged. As a qualitative synthesis, the maturity assessment reflects an analytic interpretation of the literature rather than primary measurement, and the ordinal ratings, though evidence-based, are not free of judgment. The corpus, while systematically assembled, is bounded by the chosen databases and search terms, and the Iranian focus illustrates but does not exhaust cultural contextualization. Future research should: (i) develop and empirically validate complexity metrics that operationalize Jencks' program to the level already achieved for Alexander's, for example by linking fractal dimension, entropy and network measures to perceptual and cognitive experiments; (ii) test the integrated framework through demonstration projects in historic Iranian neighbourhoods and post-occupancy evaluation; (iii) benchmark AI-based wholeness evaluators against expert and resident judgement across cultures; (iv) extend cultural contextualization to additional traditions; and (v) examine the ethical, participatory and regulatory implications of computationally governed design. By combining quantitative rigor with qualitative wisdom, and universal patterns with cultural specificity, architecture can advance toward built environments that are at once beautiful, meaningful, innovative, sustainable and just.

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