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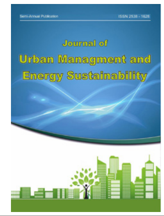

CASE STUDY RESEARCH PAPER

Development of indicators for the human environment interaction model in the Post Anthropocene era and its impact on design performance in architecture

Seyed Mosa Raeisi

Department of Humanities, Technical and Vocational University, Tehran, Iran

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ABSTRACT

In the post Anthropocene era, escalating environmental crises and climate induced disruptions have fundamentally challenged anthropocentric paradigms in architectural design, revealing their inability to respond effectively to complex ecological conditions. Although contemporary architectural discourse increasingly emphasizes sustainability, ecological responsibility, and human nature coexistence, a significant research gap remains in translating these theoretical perspectives into operational, measurable, and design-oriented frameworks. This study aims to develop and validate an indicator-based model that explains human environment interaction and evaluates its impact on architectural design performance within the post Anthropocene context. The research addresses the question of how cognitive, ecological, technological, and cultural factors can be systematically integrated into architectural design processes to enhance environmental responsiveness. A mixed-method research approach was employed, combining qualitative theoretical analysis with a quantitative Fuzzy Delphi method. Through four iterative Delphi rounds, expert opinions were collected, evaluated, and refined to achieve consensus on the most influential indicators. The analytical focus was placed on architectural design processes and their interaction with environmental systems. The findings identify human environment coexistence, natural processes in spatial formation, ecosystem compliance, ecological education, nature inspired design, building flexibility, adaptation to environmental change, and the implementation of green architecture standards as the most significant factors influencing design performance. The validated model provides a structured and evidence based framework that bridges the gap between philosophical discourse and practical architectural application. This research contributes to the advancement of resilient, sustainable, and ethically grounded architectural practices and offers a decision support tool for architects, urban designers, and policymakers addressing environmental challenges in the post Anthropocene era.

Running Title: Human Environment Interaction in Post Anthropocene Architecture

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*Corresponding Author:
Email: *smraeisi@tvu.ac.ir*
Phone: + 982166494919
ORCID: https://orcid.org/0009-0004-8734-0928

INTRODUCTION

In recent decades, the concept of architecture has undergone profound transformations in response to environmental crises and fundamental shifts in the understanding of humanity itself. These transformations are situated within a constellation of phenomena commonly described as the post Anthropocene era, a period in which the role and position of the human within the world are critically reassessed (Barke, 2018). Contrary to the traditional view that regarded humans as the central drivers of development and industrial progress, the post-Anthropocene perspective emphasizes that humanity is no longer a dominant agent within global and ecological systems, but rather a component of a complex and interdependent network (Cross, 2021). This paradigmatic shift has exerted significant influence on the fields of architecture and urban planning, necessitating a fundamental redefinition of the relationship between humans and their surrounding environment (Farrelly, 2007). In this context, emerging paradigms within architectural philosophy and related disciplines seek to offer critical, multidimensional, and sustainability-oriented responses. These paradigms underscore the necessity of strengthening the relationship between design and the natural environment, while also integrating ethical and philosophical considerations into design processes (Hayward & Samuels, 2018). At the global scale, contemporary society is increasingly characterized by the conditions of the post Anthropocene era, an era in which the human role in shaping and transforming ecological systems has been fundamentally reconfigured. The concept of the Anthropocene, which foregrounded human activity as the primary force shaping the environment, now requires critical reconsideration in light of challenges such as climate change, biodiversity loss, and escalating environmental crises (Kropf, 1998). These transformations have had direct implications for architecture, as conventional models of construction, development, and urban form have proven inadequate and unsustainable. Design approaches that once focused exclusively on human centered needs must now give way to perspectives that acknowledge, interpret, and reinforce the reciprocal relationship between humans and the environment, striving to reestablish a meaningful and balanced coexistence. Specifically, the examination of emerging architectural paradigms reveals how concepts such as anthropocentrism, sustainability, and environmental collaboration are shaping new theoretical and practical frameworks that seek to transform the conceptual and operational foundations of architecture. This evolving discourse demands rigorous and critical analysis in order to clarify both the distinctions and continuities among these paradigms (Leupen et al., 1997).

The Anthropocene is a theoretical construct that redefines the position of humanity within environmental and ecological frameworks, emphasizing trans-scalar processes such as coexistence, inter-material networks, and the non linear interactions between humans and both natural and artificial systems.

The boundaries of this concept are primarily articulated in opposition to traditional anthropocentric perspectives: the Anthropocene seeks to reposition humanity not as a dominant external force, but as an internal agent within a complex chain that is continuously subject to reciprocal influence and interaction with other actants including the environment, non-human entities, technology, and socio cultural contexts (Hanson, 2020). From this standpoint, the key distinction between the Anthropocene and green or sustainable architecture lies in the former's emphasis on redefining epistemological frameworks and the narrative logic of design, rather than focusing solely on operational or technical criteria such as resource reduction or energy efficiency, although such criteria may serve as practical manifestations of their theoretical orientation. By contrast, green architecture is primarily concerned with the use of environmentally friendly resources, the mitigation of ecological impacts in the built environment, and the enhancement of ecological performance at the project level. Sustainable architecture, adopting a systemic approach, aims to establish a long-term balance among the triads of economy, environment, and society. However, both approaches often remain implicitly anchored to preexisting ideological or philosophical assumptions regarding the human subject, without critically interrogating its positionality within broader ecological and technological systems. In this respect, the principal distinction among these three concepts becomes evident at the level of analytical depth and architectural intent. The Anthropocene functions as a theoretical framework that seeks to transform the narrative of humanity's place in the world and to reconceptualize relationships between humans, the environment, and technology. In contrast, green and sustainable architecture primarily address pragmatic design strategies and decision-making processes oriented toward environmental performance and functional sustainability, directly engaging with assessments of efficiency, durability, and ecological impact. Nevertheless, the integration of all three paradigms holds the potential to generate architectural practices that are simultaneously robust in philosophical-historical terms and viable in functional and operational execution. Alongside these theoretical shifts, existing studies indicate that the practical and executive dimensions of architectural and urban projects have remained insufficiently responsive to philosophical concepts and emerging paradigms. This gap represents a significant rupture in the application of such paradigms within professional practice and calls for research that operationalizes these theoretical frameworks within architectural processes (Moudon, 1994). Moreover, the lack of sustained and focused studies examining the impact of these emerging paradigms on architectural form, spatial organization, and design processes constitutes one of the central challenges that the present research seeks to address. Investigating how contemporary philosophies can contribute to the development of sustainable and human-centered cities is therefore of critical importance (Salama, 2008). Furthermore, analyzing these paradigms within their temporal and cultural contexts constitutes an additional step toward a deeper understanding of transformed relationships and processes. Monitoring global trends and examining successful precedents can provide effective guidance for the development of both theoretical and practical approaches (Schön, 1988). To date, however, much of the existing research in this field has concentrated primarily on critical or theoretical dimensions, resulting in a notable deficiency in applied and implementable analyses aimed at advancing sustainable and human centered urban projects. Undoubtedly, this gap implies the neglect of practical opportunities capable of exerting a meaningful influence on the future of cities and ecosystems (Strappa, 2023).

Accordingly, the present study focuses on the discontinuity between theoretical advancements in philosophical paradigms and their application within architectural practice. The primary objective is to identify strategies through which these paradigms can be effectively and pragmatically integrated into design processes, thereby enhancing the resilience, coherence, and sustainability of urban spaces. Overall, this issue necessitates not only a critical understanding of philosophical and theoretical concepts but also a strategic and practice oriented approach to architectural design and urban planning, as the future of cities depends upon the proper comprehension and utilization of these emerging paradigms. In addition, the growing intensity of environmental challenges, ecological crises, and climate change has further amplified the necessity of rethinking architectural concepts and approaches. This context directs the present research toward an in depth examination and critical evaluation of philosophical paradigms related to humanity, the environment, and architecture. The central research question thus emerges as follows: how can contemporary paradigms in architectural philosophy be redefined and operationalized in ways that not only mitigate environmental crises but also regulate the human environment relationship within a livable, sustainable, and ethically grounded framework?. Consequently, one of the principal challenges lies in examining and analyzing these emerging paradigms through interdisciplinary approaches, enabling a transition beyond purely theoretical frameworks toward the development of tangible and implementable solutions in architectural design and urbanism (Holton, 1987).

Accordingly, there is a pressing need for a comprehensive and focused study on the translation of these concepts into architectural projects, policies, and design processes. Ultimately, the aim of this research is not only to achieve a profound analytical understanding of contemporary paradigms in architectural philosophy, but also to derive practical guidelines for architects and urban planners, fostering a more integrated understanding of the human environment relationship in the post-Anthropocene era. Such an approach may contribute to the formulation of new policies and innovative strategies in architectural and urban design. Within this context, the central research question of this study is: what role do cognitive, cultural, and value-based factors play in shaping and strengthening human environment relationships in the process of designing and constructing architectural spaces in the post Anthopene era? This question directly addresses the gap between the theoretical foundations and the practical application of contemporary paradigms, seeking to clarify the actual position and function of these factors within architectural design processes. Based on this inquiry, the primary objective of the research is to elucidate the ways in which cognitive, cultural, and experiential factors influence the development of human environment relationships, and to propose a conceptual framework for integrating these approaches into both architectural theory and design practice. Such a framework aims to reinforce the linkage between philosophical perspectives and the practical imperatives of contemporary architecture, ultimately contributing to the production of robust and applicable knowledge for addressing the challenges of the post Anthropocene era.

MATERIALS AND METHODS

The Concept of the Post Anthropocene Era and Architecture

The concept of the post-Anthropocene refers to a period following the Anthropocene and signifies a fundamental shift in humanity's perception of its position and impact on the Earth. Historically, humans were predominantly viewed as agents of control and exploitation over nature; however, with the intensification of environmental crises, this role has undergone critical reconsideration (Crutzen, 2002). Crutzen was among the first to introduce the notion of the end of the Anthropocene, emphasizing that human activities have profoundly altered Earth's systems and trajectories. This paradigmatic shift has influenced not only geography and climate science but also philosophy, policymaking, and design disciplines (Malm & Hornborg, 2014).

The post-Anthropocene era provides new intellectual frameworks for rethinking humanity's role within natural systems. Contemporary architectural approaches have emerged within this conceptual milieu, redefining humans as active participants in sustainable design processes that operate in cooperation with nature rather than in dominance over it (Steffen et al., 2017). Accordingly, architectural practices have expanded beyond a sole focus on form to incorporate ecological and technological dimensions, exemplified by green architecture, ecological architecture, and smart cities. These approaches serve as living models demonstrating that architecture in the post-Anthropocene must be conceived and implemented in ways that foster balance and coexistence with natural systems. Within this framework, the concept of sustainability assumes a central role, moving beyond conventional approaches that merely emphasize resource reduction.

Modern and postmodern architectural paradigms increasingly seek to integrate advanced technologies such as renewable energy systems, recycling infrastructures, and living buildings, wherein biological systems and technological innovations converge to produce sustainable and efficient environments (Kieran & Timberlake, 2012). Such transformations necessitate not only novel design methodologies but also cultural shifts and supportive policy frameworks, as ecological instability directly affects the future of urban development and operational practices (Clark et al., 2019). Several theorists emphasize the notion of a shift in meaning, arguing that humanity's role must be reconceptualized to promote an interactive and coexistent understanding of nature. Taksin (2015) asserts that nature should no longer be perceived as an inexhaustible resource for exploitation, but rather as a dynamic ecosystem continuously interacting with human activities. Consequently, architectural design must be grounded in a deeper understanding of these systems and their reciprocal influences. While past architectural practices were largely based on anthropocentric assumptions, contemporary approaches demand a more nuanced comprehension of the interrelationships between humans and nature. In this context, emerging architectural strategies emphasize greater participation in the design process. Architectural projects that actively collaborate with natural ecosystems prioritize issues of balance and conservation of natural resources (Manschot et al., 2020). Concurrently, emerging technologies such as the Internet of Things, artificial intelligence, and green building systems play a critical role in enabling these approaches, as their capacity for data collection and analysis facilitates environmentally responsive and evidence-based design solutions (Hawkins, 2016). Beyond technology, cultural and social approaches are equally influential in shaping post-Anthropocene perspectives. Public awareness initiatives, educational programs, supportive policy mechanisms, and international collaboration constitute essential tools for advancing post-Anthropocene architectural practices. Ultimately, the goal is for architecture in this era to cease functioning as a symbol of domination and control, and instead become an expression of coexistence and equilibrium, one that preserves and promotes ecological and cultural values (Hickman, 2017). In conclusion, the post-Anthropocene concept has exerted a profound influence not only on philosophy and the sciences, but also on architecture and the fine arts, leading to fundamental transformations in both design theory and practice. This era presents a critical opportunity to reassess bio-centric principles and to develop projects in which technology and culture are harmoniously integrated to achieve sustainability and coexistence. Future-oriented research in architecture must therefore be grounded in these assumptions, placing environmental and social challenges at its core. Ultimately, the post-Anthropocene represents both an opportunity and a challenge to rearticulate humanity's role in the world and to redefine architecture as an active participant in ecological and social processes (Steffen et al., 2015).

Historical Evolution of the Human Environment Relationship in Architecture

Throughout history, the relationship between humans and the environment within the field of architecture has undergone significant transformations. In its early stages, architecture was primarily shaped by basic human needs and direct utilization of natural resources. Architects and builders in early periods largely relied on natural materials, traditional technologies, and vernacular construction methods, while nature was perceived as an abundant and seemingly inexhaustible resource. This perspective was manifested in traditional dwellings and vernacular architecture, where built forms were closely adapted to local climate, culture, and available resources. With the advent of the Industrial Revolution, perceptions of the human environment relationship shifted substantially. The emergence of new technologies, novel materials, and mass-production methods enabled the construction of larger and faster-built structures. However, these advancements simultaneously intensified negative consequences such as environmental pollution, ecosystem degradation, and excessive exploitation of natural resources. This period was largely characterized by an instrumental and exploitative view of nature, wherein the environment was regarded primarily as a means for fulfilling human needs. During the twentieth century, environmental concerns increasingly gained prominence, leading to the emergence of the concept of sustainable development as a rational response to escalating ecological crises. Architectural discourse during this period gradually gravitated toward concepts such as green architecture, sustainable design, and coexistence with nature. These shifts reflect a transition from a domination-oriented paradigm toward a responsible and participatory relationship with the environment, in which resource conservation, pollution reduction, and respect for ecological systems became central principles.

The Role of Theories in Shaping Practical Approaches

The dominion over nature paradigm, although historically effective in advancing technology and construction practices, is now largely considered obsolete or in need of critical revision. Contemporary approaches, grounded in sustainable development and ecological design, emphasize principles of responsibility and the conservation of natural resources. These approaches, alongside promoting a culture of responsible consumption, replace previous models with practical solutions such as low-energy buildings, utilization of renewable resources, and the enhancement of energy management systems. In parallel, the theory of coexistence and interaction, rooted in sustainable development principles, finds application in urban planning, green space design, and smart buildings. This paradigm is premised on the principle that humans must live alongside nature, not in opposition to it, aiming to create spaces that meet human needs while safeguarding environmental health. Furthermore, indigenous and contemporary creative theories underscore the importance of culture, local materials, and traditional technologies in crafting sustainable, contextually responsive spaces. These approaches propose design solutions attuned to local climates and cultures, which not only conserve energy and resources but also preserve regional cultural values. The human environment relationship in architecture has always been a critical and dynamic subject, especially in recent decades as environmental crises, climate change, depletion of natural resources, and ecological damage have amplified its significance. Historically, architecture was shaped primarily by individual, economic, aesthetic, and comfort related needs, with nature often perceived as an inexhaustible resource. Today, however, perceptions have shifted, and the human environment relationship is undergoing transformation. According to Feng (2021), contemporary design approaches must be based on mutual respect, collaboration, and balance between humans and nature to mitigate ecological and environmental damages and establish sustainable, symbiotic relationships. In this renewed perspective, nature is no longer merely a resource for human needs but a living system continuously interacting with human activities. As noted by Luo (2015), the modern understanding of nature views it as a dynamic system governed by specific laws and harmonies, requiring intelligent management and respect. Consequently, green and ecological architecture has emerged, leveraging modern technologies, sustainable materials, and resource efficient strategies. Examples such as green walls, living spaces, and recycled materials illustrate a model where humans are regarded as co agents with nature, tasked with its protection (Schäfer et al., 2019). Emerging technologies and intelligent systems play a crucial role in realizing projects that maintain positive and harmonious relationships with the environment. Technologies such as water collection and purification systems, renewable energy sources, low energy buildings, and the Internet of Things enable the design of balanced, sustainable, and human centered spaces (Jones et al., 2018). These tools act as instruments to implement ecologically-oriented approaches, significantly improving construction and operational practices, and provide opportunities for creating living and working spaces with minimal environmental impact. Practically, numerous exemplary projects demonstrate designs based on positive interactions with nature. Living buildings, smart cities, vertical gardens, and green public spaces exemplify architecture serving as a facilitator for sustained human environment coexistence. These projects, rather than exploiting natural resources, aim to restore and improve them, advancing sustainable development (Hickman, 2017). They reveal that design founded on biodiversity respect, collaboration with natural elements, and utilization of green technologies can enhance environmental quality and mitigate harmful impacts. Alongside practical measures, education and cultural development play pivotal roles in transforming human attitudes toward the environment. Educational programs, public awareness initiatives, and collective activities significantly influence individual and collective behaviors (Hornborg and Malm, 2014). Moreover, government policies and international regulations must encourage green construction and enforce waste reduction and pollution control. Actions such as providing financial incentives, facilitating green permits, and promoting sustainable development concepts are critical in fostering substantive changes in design, construction, and operational practices. Consequently, the human environment relationship in architecture has evolved from one of exploitation and dominance to interaction, coexistence, and responsibility. The future of this relationship depends on joint efforts, intelligent policymaking, effective use of emerging technologies, and societal cultural and attitudinal shifts. Architecture must act as a mediator and facilitator of this relationship, ensuring that built environments satisfy immediate human needs while promoting sustainable resource use and ecological balance. This contemporary approach opens opportunities for green cities, efficient and livable buildings, and environmental restoration. Overall, the focus should be on developing operational strategies, innovative technologies, and public education to embed a culture of coexistence and respect between humans and nature as a core principle in the design and construction of future built environments. These transformations lay the foundation for a sustainable, healthy, and balanced future for coming generations, demonstrating that an active and responsible approach to the environment is the only viable path for managing current crises while upholding a philosophy rooted in respect, collaboration, and responsibility.

Human Environment Relationship in Architecture

Given the extensive developments in environmental conditions and emerging technologies, the human environment relationship in architecture faces numerous challenges and opportunities. One of the most pressing challenges is addressing environmental crises such as climate change, depletion of natural resources, air and water pollution, which necessitate innovative approaches and comprehensive policymaking. In this context, architects and designers must move towards spatial designs that prioritize sustainability, green spaces, energy efficiency, and ecosystem restoration. Conversely, there are significant opportunities. Advanced technologies, such as smart buildings, renewable energy collection systems, green technologies, and sustainable local materials, enable the creation of improved and cost effective spaces. These capabilities, combined with ecological design principles, provide an opportunity to transform architecture into a tool for restoring the human nature relationship. One key avenue is the promotion of green architecture and livable cities, where all urban elements including green spaces, clean transportation systems, and adaptable designs interact harmoniously with the environment. Furthermore, the participation of local communities, citizens, and stakeholders in design and decision-making processes plays a crucial role in creating sustainable and symbiotic spaces. This approach strengthens cultural values, preserves resources, and reduces negative environmental impacts. Another important opportunity lies in the development of supportive governmental and international policies that foster sustainable architectural innovation. The formulation of appropriate regulations, provision of financial incentives, and promotion of a culture of conservation and responsible resource utilization are strategies that can significantly influence design attitudes and practices. Ultimately, the human environment relationship in architecture should be grounded in principles of coexistence, responsibility, and harmony with nature. The future of this relationship depends on societal capabilities, ideologically informed policies, and emerging technologies that, in conjunction with environmental preservation, enable healthier, more sustainable, and improved living conditions for future generations (Tab1 and 2).

Table 1: Summary of Theories and Thinkers Related to Human Cognition in Relation to the Environment in the Architectural Process

No	Theorist / Author	Year	Book / Work	Description
1	Ian McHarg	1969	Design with Nature	Introduction of ecological design concepts and the importance of considering ecosystems in architecture
2	William McDonough	2002	Cradle to Cradle Design	Principles of sustainable design and focus on material life cycles in buildings
3	Stewart Brand	1994	How Buildings Learn: What Happens After They're Built	Principles of sustainable design and focus on material life cycles in buildings
4	Rachel Carson	1962	Silent Spring	Impact of human activities on the environment and the need for responsible design approaches
5	David Orr	1992	Ecological Literacy	Education and enhancement of ecological understanding and human nature relationships in architecture
6	Christopher Alexander	1977	The Timeless Way of Building	Human-centered and harmonious design approach with natural and cultural environments
7	Peter Newman & Ken Yeang	1996	Green Urbanism	Green architecture, metropolitan design, and interaction with nature
8	Michael Hough	2002	The Upcycle	Reuse and enhancement of material cycles in sustainable architecture
9	Janine Benyus	2002	The Upcycle	Reuse and enhancement of material cycles in sustainable architecture
10	Janine Takahashi	1997	Biomimicry	Nature-inspired design in buildings and urban spaces

11	Richard Rogers & Renzo Piano	2005	In the Bubble	Design approaches based on sustainability and human environment coexistence
12	Sarah Wilkinson	2011	Building for a Limited Planet	Green architecture and responsibility in constructing sustainable buildings
13	Peter Newman & Ken Yeang	2010	Urban Ecology and Design	Architecture and interaction with local ecosystems
14	David Gissen	2010	Subnature: Architecture's Other Environments	Architecture and interaction with local ecosystems
15	Neri Sanoff	2000	Participatory Design in Architecture	Stakeholder participation in the design process and environmental interaction
16	William Mitchell	2009	Me++: The Cyborg Self and the Networked City	Impact of technology and human environment connectivity in urban architecture
17	Susan Sanzhi	2007	Eco-Friendly Architecture	Responsible architectural practices and environmental impacts
18	Krista van Wilt	2014	Ecological Urbanism	Innovative approaches in green architecture and urban planning
19	Michael Speaks	2010	The Social Logic of Space	Influence of architectural space on human relationships and the environment
20	Bill McKibben	2007	Deep Economy	Green economy, efficiency, and coexistence with nature in construction

Table 2: Summary of Key Concepts and Topics Related to Human Cognition in Relation to the Environment in the Architectural Process

No	Theorist / Author	Key Concepts / Topics	Brief Description
1	Ian McHarg	Design with Nature, Ecosystems, Ecology in Architecture	Importance of understanding and respecting natural structures for sustainable and environmentally harmonious spatial design
2	William McDonough	Material Life Cycle, Redesign, Waste-Free Buildings	Focus on material reuse, design for recycling, and sustainable construction practices
3	Stewart Brand	Building Adaptation, Learning, Durability & Sustainability	Emphasis on flexibility and adaptability of buildings and architectural spaces over time and changing needs
4	Rachel Carson	Human Impacts on Environment, Environmental Responsibility	Environmental damage and the necessity of individual and collective responsibility in protecting nature
5	David Orr	Ecological Education, Trust in Nature, Ecological Literacy	Necessity of education and enhanced understanding of human–nature relationships for responsible architectural practices
6	Christopher Alexander	Human-Centered Design, Architectural Harmony, Natural Patterns	Focus on architectural design based on human relations, culture, and natural patterns
7	Peter Newman & Ken Yeang	Green Architecture, Sustainable Cities, Design with Nature	Development of cities based on ecological principles, incorporating green and ecological buildings

8	Michael Hough	Natural Processes, Sustainable Development, Natural Cities	Role of ecological processes in shaping urban spaces and ecosystem-aligned design
9	Janine Benyus	Bio-Inspired Design, Biomimicry, Nature-Based Design	Learning from natural processes to create creative solutions in architecture and green technologies
10	Takahashi	Sustainable Design, Technology, Human–Nature Coexistence	Innovative approaches for creating sustainable spaces focused on human–environment interaction
11	Richard Rogers & Renzo Piano	Responsible Buildings, Sustainability, Green Architecture	Design of buildings with low environmental impact and high accountability
12	Sarah Wilkinson	Urban Ecology, City Design, Environmental Health	Linking architecture with ecosystem protection in urban spaces
13	David Gissen	Environmental Subconscious, Subterranean Processes, Human-Centered Design	Impact of unconscious and underlying processes on shaping architectural spaces and their relationship with nature
14	Neri Sanoff	Participatory Design, Stakeholder Collaboration, Democratic Design	Importance of collective participation and stakeholder interaction in the design process
15	William Mitchell	Technology, Smart Cities, Digital–Environmental Interaction	Role of technology and digital tools in shaping smart, adaptive urban architecture
16	Susan Sanzhi	Green Architecture, Environmental Responsibility, Sustainable Design	Practical strategies and standards for responsible and eco-friendly architecture
17	Krista van Wilt	Ecological Urbanism, Green Design, Natural Spaces	Development of sustainable cities with focus on interaction with local ecosystems
18	Michael Speaks	Social Spaces, Human Relations, Environmental Impacts	Influence of architectural space on human relationships and environmental health
19	Bill McKibben	Green Economy, Responsible Development, Sustainable Consumption	Promotion of economic and cultural concepts related to conservation and resource management

In the field of architecture during the post Anthropocene era, emerging concepts and approaches are shaped by contemporary theories regarding the human environment relationship. A central principle within this framework is the emphasis on an intelligent and sustainable coexistence between humans and the environment, aiming for a continuous, responsible, and harmonious interaction with nature. Concurrently, the development of green and smart technologies plays a crucial role in improving efficiency and mitigating negative environmental impacts, such that future building systems should be designed based on advanced technologies and clean energy infrastructures. Ecosystemic and ecological compatibility concepts in architectural design indicate that construction must ensure alignment with ecosystems and natural processes, rather than relying solely on resource extraction. In this context, the focus on sustainability and resource management serves as a fundamental strategy for reducing consumption and minimizing waste, enabling buildings and cities to be self-sufficient and recyclable, while enhancing the role of digital and intelligent technologies in this process. Biomimicry, or technology inspired by natural systems, has emerged as a novel approach in architectural design. This concept asserts that natural strategies and ecological adaptations can provide long term solutions to environmental challenges. Simultaneously, the concept of the human in contemporary architecture is undergoing a redefinition from a purely anthropocentric perspective to an informed and responsible individual whose presence within built spaces emphasizes ecological awareness and a profound connection with nature.

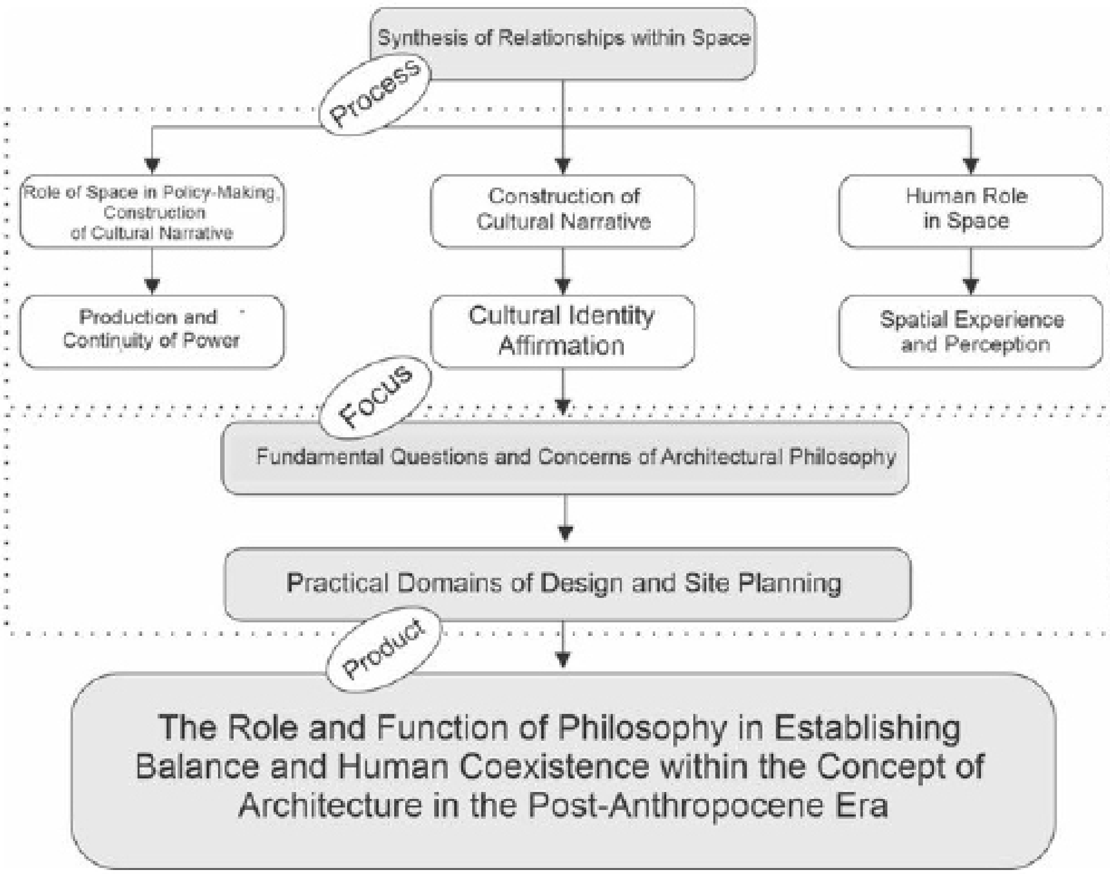

Figure 1: Conceptual model of spatial relationships in architecture based on process, focus, and outcome

This diagram provides a coherent conceptual framework for elucidating the role of philosophy in architectural space, explaining hierarchically the relationships among space, humans, culture, and power from conceptual to practical levels. At the highest level, the synthesis of relationships in architectural space is presented as the focal point, representing the dialectical link among three primary components: the role of humans in space, the role of space in governance, and the construction of cultural narratives. These three parallel pathways indicate that space is not merely a physical substrate; simultaneously, it shapes human perceptual experience, is reproduced through power and political processes, and functions as a medium for narrating and consolidating cultural identity. Along these pathways, spatial experience and human perception generate meaning, the role of space in governance leads to the continuity and reproduction of power, and the construction of cultural narratives ultimately consolidates cultural identity. At a deeper level, these outcomes connect to the fundamental questions and concerns of architectural philosophy, where architecture is interrogated not merely as a building technique but as a reflective, intellectual act. From this stage, the diagram transitions to practical domains, illustrating how these philosophical questions manifest in design and policymaking. Ultimately, the entire process culminates in an overarching synthesis emphasizing the role and function of philosophy in establishing balance and human coexistence within the framework of architecture in the Post Anthropocene era, suggesting that philosophy transforms architecture into a tool for rethinking human space world relations under contemporary crises, elevating it from a purely technical response to an ethical, cultural, and existential stance. The role of digital and intelligent technologies in the design and construction process represents another key concept with multiple branches from smart infrastructures based on the Internet of Things to AI-driven visual analyses that contribute to flexible and multifunctional architectural production. Additionally, the development of clean energy sources and interactive energy systems plays a strategic role in reducing the negative environmental impacts of buildings, thereby creating urban areas that are resilient and adaptable to climate and natural crises. Alongside these factors, attention to the formation of flexible and multifunctional spaces, while considering vulnerability and resilience, is of high importance. Public awareness and cultural education regarding environmental responsibility in architecture are essential for instilling sustainable development values. The use of recycled and low-consumption materials, alongside dynamic designs adaptable to changing conditions, represents another fundamental element in Post-Anthropocene architectural approaches. Ultimately, the development of smart cities responsive to ecological needs, combined with sustainable development goals, shapes the trajectory of future architecture. Based on a synthesis of theoretical foundations, research background, and potential considerations regarding the subject and research variables, twenty potential factors influencing the main topic can be delineated as follows: (Tab3)

Table 3: Summary of Influential Factors Related to Human Awareness in Relation to the Environment in the Architectural Process in the Post-Anthropocene era

No	Key Factor	Concept Type	Description	Importance	Application Example
1	Intelligent human environment coexistence	Bio centric concept	Sustained, adaptive, and responsible interaction between humans and nature	Very High	Design of green and sustainable cities
2	Green and smart technologies	Technology	Use of advanced technologies to improve efficiency and reduce environmental impact	Very High	Energy efficient buildings
3	Ecosystem and ecological compatibility	Design approach	Alignment and integration of architectural design with natural processes	High	Ecological spaces
4	Sustainability and resource management	Strategic approach	Reduction of resource consumption and enhancement of construction efficiency	Very High	Use of low consumption and recycled materials

5	Digital and smart technologies	Technology	Application of intelligent and digital tools in design and construction processes	High	Smart buildings and Internet of Things (IoT)
6	Biomimetic technology and natural systems	Innovative approach	Emulating natural strategies to solve design challenges	High	Buildings based on natural structures
7	Biomimetic technology and natural systems	Innovative approach	Emulating natural strategies to solve design challenges	High	Buildings based on natural structures
8	Redefining the concept of humans in architecture	Cultural and ethical concept	Humans as aware, responsible agents integrated with nature	High	Interactive and awareness oriented spaces
9	Clean energy systems and interactive production	Technology	Renewable energy sources with intelligent production and consumption systems	Very High	Solar and wind energy systems
10	Flexible and multi purpose spaces	Architectural design	Versatile, adaptable spaces for diverse functions	High	Transformable residential and office buildings
11	Environmental awareness and cultural promotion	Cultural approach	Promoting responsible environmental behavior within communities	High	Educational programs and cultural campaigns
12	Recycled materials and low energy buildings	Materials and construction	Use of recycled materials and design of energy efficient, sustainable buildings	High	Low energy and recycled-material buildings
13	Dynamic and adaptable design	Architectural approach	Designing spaces that can change and adapt to evolving needs	High	Multi purpose and adaptable buildings
14	Smart and responsive city development	Urban approach	Developing smart cities focusing on resource efficiency and sustainability	High	Intelligent urban management systems
15	Advanced architectural technologies	Technology	Utilization of AI, robotics, and other advanced tools in design and construction	High	Automated and robotic construction systems
16	Biophilic landscapes and natural vistas	Aesthetic approach	Attention to natural views and ecological landscapes in architectural design	Medium	Parks and urban green spaces
17	Human-nature interaction	Social approach	Spaces fostering enhanced interaction between humans and nature to improve quality of life	High	Open spaces and community centered areas

18	Development of renewable and clean energy sources	Technology	Harnessing renewable energy to reduce dependency on fossil fuels	High	Independent solar and wind energy systems
19	Community based and participatory design	Participatory approach	Active engagement of stakeholders and users in the design process	High	Participatory urban planning
20	Energy storage and recovery technologies	Technology	Energy storage systems to enhance sustainability and efficiency	High	Large scale batteries and energy storage systems

CONCLUSION

These 20 factors, serving as the initial items for the Delphi questionnaire, were directly derived from the theoretical foundations and conceptual framework of the Human Environment Interaction Model in the Post-Anthropocene Era and its impact on architectural design performance. These factors include: ecosystem compliance, use of material life cycle and building redesign, building flexibility and adaptability to environmental changes, reducing human activities' environmental impacts, enhancing ecological education and awareness, human centered design and harmony with natural and cultural environments, development of sustainable cities and green architecture, consideration of natural processes in shaping urban spaces, nature-inspired design and biomimicry, sustainable design with a human-environment coexistence approach, environmental responsibility in buildings, integration of urban ecology and local design, consideration of unconscious processes in shaping architectural spaces, stakeholder participation and participatory design, smart technologies and smart cities, application of green architecture standards and practical solutions, ecological urban design and natural spaces, the architectural environment's impact on human relations and environmental health, promotion of green economy and sustainable consumption, and development of practical strategies to bridge theory and practice in architectural design. These factors provide a basis for assessing their influence on architectural design performance and are used in subsequent research stages as proposed indicators for evaluating the Human Environment Interaction Model.

Findings from the First Round of the Delphi Method

In the first round, the panel members identified 17 out of 24 factors extracted from the conceptual framework and theoretical foundations as highly or very highly influential in shaping the framework of indicators for the Human Environment Interaction Model in the Post-Anthropocene Era and Its Impact on Architectural Design Performance.The detailed and comprehensive results of the first round questionnaire distribution are presented in the table above. Factors such as Human-Centered Design, Urban Ecology and Local Design, Hidden Processes in Architectural Space Formation, Participatory Design, Architectural Space Quality on Human Relations, Harmony with Natural and Cultural Environment, and Environmental Health were excluded from the Delphi process due to mean scores below 2.5, indicating lower perceived influence by the expert panel. These results highlight that concepts emphasizing ecological literacy, ecosystem observance, green architecture standards, biomimicry, and practical strategies linking theory to design practice are considered most critical in forming a resilient and sustainable human-environment interaction model within architectural processes.

Table 4: First Round of the Fuzzy delphi Method in Developing Proposed Indicators Influencing the Human Environment Interaction Model in the Post Anthropocene Era and Its Impact on Architectural Design Functionality

No.	Factor	Mean Score	Standard Deviation	Minimum	Maximum
1	Observance of Ecosystems	3.45	0.45	1	5
2	Use of Material Life Cycle and Building Redesign	2.75	0.42	1	5
3	Building Flexibility	3.54	0.55	1	5
4	Effects of Human Activities on the Environment	3.33	0.47	1	5
5	Ecological Education and Literacy	3.73	0.39	1	5
6	Human Centered Design	2.42	0.35	1	5
7	Sustainable Urban Development	2.66	0.51	1	5
8	Natural Processes in Space Formation	3.69	0.45	1	5
9	Biomimicry / Nature-Inspired Design	3.56	0.38	1	5
10	Human Environment Coexistence	3.42	0.32	1	5
11	Environmental Responsibility	2.57	0.31	1	5
12	Urban Ecology and Local Design	2.44	0.29	1	5
13	Hidden Processes in Architectural Space Formation	2.26	0.27	1	5
14	Hidden Processes in Architectural Space Formation	2.21	0.25	1	5
15	Smart Technologies	2.52	0.41	1	5
16	Implementation of Green Architecture Standards	3.77	0.36	1	5
17	Ecological Urbanism	3.12	0.35	1	5
18	Architectural Space Quality on Human Relations	2.12	0.28	1	5
19	Green Economy	2.65	0.31	1	5
20	Practical Strategies for Linking Theory and Practice	3.87	0.47	1	5
21	Adaptation to Environmental Changes	3.36	0.40	1	5
22	Harmony with Natural and Cultural Environment	2.12	0.35	1	5
23	Environmental Health	2.45	0.32	1	5
24	Sustainable Consumption	2.25	0.22	1	5

Second Round of the Delphi Method

Following the completion of the first round and the evaluation of the panel experts' opinions regarding the proposed factors extracted from theoretical foundations, as well as incorporating the suggestions received from panel members, all factors derived from the theoretical basis along with the first round mean scores and previous opinions of the same members were represented to all panel experts in this round as a precautionary measure. In this second round, the panel identified 11 out of the 17 proposed factors as having high or very high influence (with mean scores greater than 3), which significantly impact the conceptual framework for developing indicators of the Human-Environment Interaction Model in the Post Anthropocene Era and Its Effect on Architectural Design Performance. Consequently, the factors Use of Material Life Cycle and Building Redesign, Sustainable Urban Development, Environmental Responsibility, Smart Technology, Green Economy, and Sustainable Consumption were removed from the Delphi process. The detailed and comprehensive results of the second-round questionnaire distribution are presented in the table below.

Table 5: Second Round of the Fuzzy delphi Method in Developing Proposed Indicators Influencing the Human Environment Interaction Model in the Post Anthropocene Era and Its Impact on Architectural Design Functionality

No.	Factor	Mean Score	Standard Deviation	Minimum	Maximum
1	Compliance with Ecosystem	3.65	0.38	2	5
2	Use of Material Life Cycle and Building Redesign	2.91	0.36	2	5
3	Building Flexibility	3.75	0.41	2	5
4	Effects of Human Activities on the Environment	3.62	0.40	2	5
5	Ecological Education and Literacy	3.82	0.32	2	5
6	Sustainable Urban Development	2.83	0.44	2	5
7	Natural Processes in Space Formation	3.86	0.32	2	5
8	Biomimicry (Learning from Nature)	3.75	0.32	2	5
9	HumanEnvironment Coexistence	3.52	0.27	2	5
10	Environmental Responsibility	2.77	0.29	2	5
11	Smart Technology	2.78	0.33	2	5
12	Application of Green Architecture Standards	3.82	0.29	2	5
13	Ecological Urbanism	3.35	0.28	2	5
14	Green Economy	2.89	0.30	2	5
15	Practical Strategies for Bridging Theory and Practice	3.98	0.42	2	5
16	Adaptation to Environmental Changes	3.66	0.35	2	5
17	Sustainable Consumption	2.45	0.19	2	5

Third Round

In the third round of developing the proposed indicator framework, the indicators affecting the formulation of the Human Environment Interaction Model in the Post Anthropocene era and their impact on architectural design performance were presented to all panel experts, along with the average scores from the second round and their previous responses. Detailed and comprehensive results related to the implementation of the third round of the questionnaire distribution are provided in the table below. Accordingly, the factor Ecological Urbanism was removed due to an average score of 3.95.

Table 6: Second Round of the Fuzzy delphi Method in Developing Proposed Indicators Influencing the Human Environment Interaction Model in the Post Anthropocene Era and Its Impact on Architectural Design Functionality

No.	Factor	Mean Score	Standard Deviation	Minimum	Maximum
1	Ecosystem Compliance	4.05	0.29	3	5
2	Building Flexibility	4.15	0.32	3	5
3	Impacts of Human Activities on the Environment	4.02	0.35	3	5
4	Ecological Education and Literacy	4.22	0.29	3	5
5	Natural Processes in Spatial Formation	4.46	0.27	3	5
6	Nature-Inspired Design (Biomimicry)	4.15	0.28	3	5
7	Human Environment Coexistence	4.92	0.21	3	5
8	Implementation of Green Architecture Standards	4.22	0.26	3	5
9	Ecological Urbanism	3.95	0.31	3	5
10	Practical Strategies for Linking Theory and Practice	4.38	0.33	3	5
11	Adaptability to Environmental Changes	4.06	0.30	3	5

Fourth Round of the Delphi Method

Following the completion of the third round of the Delphi process and the evaluation of expert panel opinions regarding the proposed factors extracted from the theoretical foundations, as well as the incorporation of feedback provided by panel members, a fourth round was conducted to ensure robustness and consensus stability. In this round, all factors derived from the theoretical framework were re-presented to the entire panel of experts, accompanied by the mean scores obtained in the previous round and each expert's prior responses, allowing for informed reconsideration and refinement of judgments. The results of this round indicate that the panel members identified 10 out of the 11 proposed factors as having high to very high influence, with mean scores exceeding 4.00. These factors were therefore confirmed as significantly influential in shaping the proposed framework for developing indicators of the Human Environment Interaction Model in the Post Anthropocene Era and its impact on architectural design performance. Furthermore, the Kendall's coefficient of concordance (W) for the experts' rankings of the selected factors was calculated as 0.790, indicating a high level of agreement and strong consensus among panel members. This result confirms the reliability of the Delphi process outcomes and demonstrates substantial convergence in expert judgments regarding the prioritization of the proposed indicators (Tab7)

Table 7: Fourth Round of the Fuzzy Delphi Method in Developing Proposed Indicators Influencing Indoor Air Quality in Central Courtyard Houses in Hot and Humid Climates, with Emphasis on the Concept of Natural Ventilation

No.	Factor	Mean Score	Standard Deviation	Minimum	Maximum
1	Ecosystem Compliance	4/07	0/25	4	5
2	Building Flexibility	4/17	0/27	4	5
3	Impacts of Human Activities on the Environment	4/04	0/29	4	5
4	Ecological Education and Literacy	4/25	0/20	4	5
5	Natural Processes in Spatial Formation	4/49	0/19	4	5
6	Nature-Inspired Design (Biomimicry)	4/18	0/21	4	5
7	Human Environment Coexistence	4/96	0/18	4	5
8	Implementation of Green Architecture Standards	4/27	0/21	4	5
9	Ecological Urbanism	4/27	0/21	4	5
10	Practical Strategies for Linking Theory and Practice	4/42	0/29	4	5
11	Adaptability to Environmental Changes	4/12	0/25	4	5

Reasons for Stopping the Delphi Survey

The results of the four rounds of the Delphi method in this study indicate that a consensus was achieved among the panel members for the following reasons, and further rounds could be reasonably discontinued:

1.Consensus on Key Factors in the Second Round:

In the second round, more than 50% of the panel members selected 17 influential factors in developing the proposed indicator framework that affected the indicators of the Human Environment Interaction Model in the Post Anthropocene Era and its impact on architectural design performance, with mean scores above 2.5. In other words, the identification of these 17 key factors by over half of the experts represents a strong form of consensus. This agreement not only enhances the validity of the study but also formally recognizes the importance of these factors in the process of developing indicators for the Human Environment Interaction Model. When a group of experts emphasizes specific factors, it underscores their critical role and highlights the need for greater attention to them in future design practices.

2.Reduction in Standard Deviation:

The standard deviation of the panel members' responses regarding the importance of the factors significantly decreased from the previous rounds to the fourth round. This marked reduction indicates that panel members' perspectives became increasingly aligned, likely due to ongoing discussions and information exchange in previous rounds, leading to a shared understanding of key issues. A lower standard deviation reflects that the identified factors have reached a level of agreement and shared comprehension, which can translate into a more unified voice within the community of designers and architects.

3.Kendall's Coefficient of Concordance in Round Three:

The Kendall's coefficient of concordance (W) for the panel members' ranking of the factors in the third round was 0.790. Given that the panel included more than ten members, this coefficient represents a highly significant result. A Kendall's W of 0.790 provides a clear quantitative indication of convergence among the panelists' opinions. Considering the relatively large number of panel members, this level of concordance demonstrates the scientific reliability of the results. In other words, the convergence observed is promising and can facilitate better decision-making and more effective strategies in architectural design.

4.Stabilization of Consensus:

The Kendall's coefficient of concordance for the ranking of the 10 most influential factors affecting the development of the proposed indicators for shadow effects on the perception of architectural form increased by only 0.025 from the second to the third round. This minimal increase indicates that there was no significant growth in consensus across consecutive rounds. In other words, the lack of substantial change in Kendall's W between the second and third rounds suggests that the consensus process had reached a stabilization point, and additional rounds of the survey would likely yield limited new insights. This can be considered a positive indicator, as it shows that the group has reached a shared understanding and can now focus on the practical implementation of the results.

Expert Ratings of the Factors:

The scores assigned to the factors by the experts and specialists indicate that Human Environment Coexistence and Natural Processes in Spatial Formation received the highest mean scores of 4.96 and 4.49, respectively. Consequently, these factors exert the greatest influence in explaining the indicators affecting the development of the Human Environment Interaction Model in the Post Anthropocene Era and its impact on architectural design performance during the process of constructing the indicator framework.

Analysis of the Results from the First Phase of the Delphi Method

The results of the first phase of the Delphi method indicate that the mean scores of the factors in this phase were widely distributed, and the standard deviations were relatively high. Means ranged from 2.12 (Harmony with Natural and Cultural Environment) to 3.87 (Practical Strategies for Linking Theory and Practice), and response ranges spanned from 1 to 5. The highest standard deviation was observed for Building Flexibility (SD = 0.55), while the lowest corresponded to Sustainable Consumption (SD = 0.22), reflecting varying degrees of dispersion in expert opinions. The coefficient of variation (CV = SD/Mean) ranged between 0.064 and 0.10 in this phase. Due to this dispersion, applying a mean threshold of 2.5 resulted in the exclusion of seven factors from further consideration. In the second phase, after the initial refinement, the mean scores of the factors increased, and their variation ranges became narrower. Means in this phase ranged from 2.35 to 3.98, and the standard deviation of most factors decreased by 0.03 to 0.11 compared to the first phase, indicating reduced dispersion and relative convergence of expert opinions. Response ranges narrowed to 2–5, and applying a mean threshold of 3 led to the elimination of six factors with lower averages. The highest mean in this phase was for Practical Strategies for Linking Theory and Practice (3.98), while the lowest was for Ecological Urbanism (2.35). The decrease in SD relative to the mean indicates greater statistical reliability of the responses. The third phase results show that the mean scores of the remaining factors increased further to a range of 3.95–4.92, with response ranges limited to 3–5. Standard deviations of most factors decreased further, falling between 0.21 and 0.35, reflecting higher convergence and concentration of evaluations. Coefficients of variation for most factors ranged from 0.05 to 0.08. The highest mean was for Human-Environment Coexistence (4.92) and the lowest for Ecological Urbanism (3.95). Only one factor with a mean below the threshold of 4 was excluded in this phase. In the fourth phase, the mean scores stabilized, with changes relative to the third phase being less than 0.05. Means ranged from 4.07 to 4.96, and standard deviations reached their lowest values throughout the process (0.18–0.25), indicating full numerical consensus. Response ranges were limited to 4–5, and no factors were removed. The highest mean was for Human-Environment Coexistence (4.96), and the lowest for Adaptation to Environmental Changes (4.12). The SD-to-mean ratio (CV ≤ 0.06) indicates high stability of evaluations and strong concentration of expert responses. Overall, the progressive increase and stabilization of mean scores, the gradual and significant reduction in standard deviations, the narrowing of response ranges, and the decreasing coefficients of variation over the four phases of the Delphi method demonstrate that the process achieved statistically reliable convergence. The increase in means alongside the reduction in SD and the narrowing of response ranges reflect a strong quantitative consensus and the stabilization of the final factors, which can serve as a statistical foundation for subsequent research phases or model development.

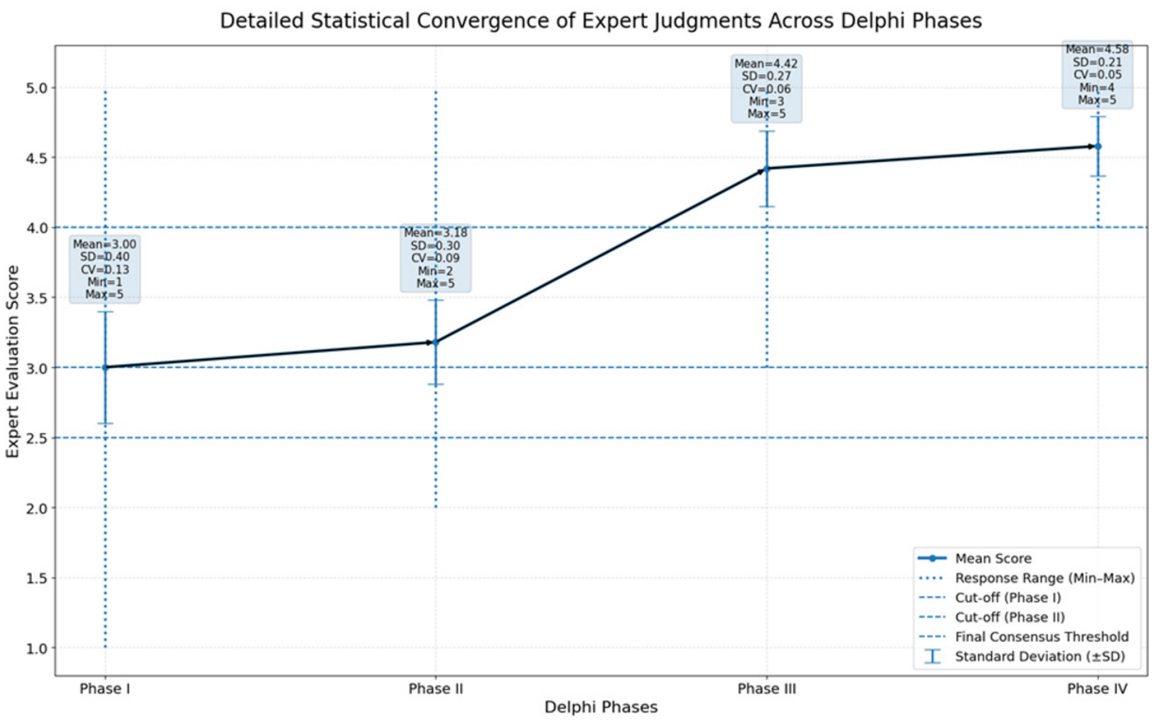

Figure 2: Convergence of Expert Ratings in the Four Phases of the Delphi Method: Mean Scores, Standard Deviations, and Response Ranges of Proposed Factors

REFERENCES

Barke, M. (2018). The importance of urban form as an object of study. In V. Oliveira (Ed.), Teaching urban morphology (pp. 11–30). Springer International Publishing. https://doi.org/10.1007/978-3-319-76126-8_2

Bertrand, E., & Chillet, C. (2016). Le macellum Liviae à Rome : vrai ou faux monument augustéen? Méfra, 128(2), 469–485. https://doi.org/10.4000/mefra.3807

Bettencourt, L. M. A., & West, G. B. (2010). A unified theory of urban living. Nature, 467(7318), 912–913.

Bettencourt, L. M. A., Lobo, J., Strumsky, D., & West, G. B. (2010). Urban scaling and its deviations: Revealing the structure of wealth, innovation, and crime across cities. PLoS One, 5(11), e13541. https://doi.org/10.1371/journal.pone.0013541

Brott, S. (2012). Modernity's opiate, or, the crisis of iconic architecture. Log, 26, 49–59.

Clark, G., Nakushima, Y., & Loorbach, D. (2019). Transition pathways for urban sustainability: Integrating social and technological innovations. Environmental Innovation and Societal Transitions, 31, 142–154.

Corbusier, L. (1986). Towards a new architecture. Dover Publications.

Cordero, R. (2014). Crisis and critique in Jürgen Habermas's social theory. European Journal of Social Theory, 17, 497–515.

Cross, N. (2021). Engineering design methods (5th ed.). Wiley.

Crutzen, P. J. (2002). The anthropocene. Nature, 415(6867), 23.

Ellis, S. J. R. (2018). The Roman retail revolution: The socio-economic world of the taberna. Oxford University Press.

Farrelly, L. (2007). The fundamentals of architecture. AVA Publishing SA.

Frampton, K. (1992). Modern architecture: A critical history (3rd ed.). Thames & Hudson.

Gilbert, A. S. (2019). The crisis paradigm: Description and prescription in social and political theory. Palgrave Macmillan.

Hanson, J. W. (2016). An urban geography of the Roman world, 100 BC to AD 300. Archaeopress.

Hanson, J. W. (2020). Using city gates as a means of estimating ancient traffic flows. PLoS One, 15(2), e0229580. https://doi.org/10.

Hawkins, D. (2016). Data-driven urban planning: The role of AI and IoT. Smart City Journal.

Hayward, R., & Samuels, I. (2018). Moving urban morphology from the academy to the studio: The use of urban tissues in teaching and continuing professional development. In V. Oliveira (Ed.), Teaching urban morphology (pp. 281–296). Springer International Publishing. https://doi.org/10.1007/978-3-319-76126-8_16

Hickman, L. (2017). Cities and ecological restoration: Towards sustainable urban development. Urban Ecology Review, 5(2), 77-95.

Hickman, L. (2017). On species and the eco-social. Environmental Philosophy, 14(2), 123–144.

Holton, R. J. (1987). The idea of crisis in modern society. British Journal of Sociology, 38, 502–520.

Hornborg, A., & Malm, A. (2014). The geology of mankind? A critique of the anthropocene narrative. The Anthropocene Review, 1(1), 62–69.

Jones, L., Ahmed, R., & Kim, S. (2018). Smart technologies and sustainable architectural practices. Technology and Environment, 10(4), 112-128.

Kieran, S., & Timberlake, J. (2012). Refashioning architecture: A look at the principles of sustainable design. Wiley.

Kropf, K. (1998). Typological zoning. In A. Petruccioli (Ed.), Typological process and design theory (pp. 127–140). Aga Khan Program for Islamic Architecture.

Leupen, B., Christoph, G., Körnig, N., Lampe, M., & De Zeeuw, P. (1997). Design and analysis. 010 Publishers.

Malm, A., & Hornborg, A. (2014). The geology of mankind? A critique of the Anthropocene narrative. The Anthropocene Review, 1(1), 62–69.

Manschot, S., Bontje, M., & Beringer, T. (2020). Urban ecosystems and sustainable design principles. Urban Studies, 57(2), 245–262.

Moudon, A. V. (1994). Getting to know the built landscape: Typomorphology. In K. A. Franck & L. H. Schneekloth (Eds.), Ordering space: Types in architecture and design (pp. 289–311). Van Nostrand Reinhold.

Salama, A. M. (2008). A theory for integrating knowledge in architectural design education. Archnet-IJAR, International Journal of Architectural Research, 2(1), 100–128.

Schäfer, S., Müller, T., & Zhang, Y. (2019). Green buildings and ecological architecture: Integrating technology and sustainability. Eco-Design Journal, 7(1), 23-38.

Schön, D. A. (1988). Toward a marriage of artistry & applied science in the architectual design studio. Journal of Architectural Education (1984-), 41(4), 4–10. https://doi.org/10.2307/1425007

Steffen, W., Rockström, J., Lenton, T. M., et al. (2017). Trajectories of the Earth System in the Anthro-

pocene. Proceedings of the National Academy of Sciences, 115(33), 8252–8259.

Strappa, G. (2023). The notion of enclosure in the formation of special building type. In A. Petruccioli (Ed.), Typological process and design theory (pp. 91–113). Aga Khan Program for Islamic Architecture.

Tixsen, M. (2015). Rethinking ecological design: Contributions of systems thinking. Journal of Design and Science.

Venturi, R. (2017). Complexity and contradiction in architecture (2nd ed.). The Museum of Modern Art.