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Original Research Article

Beyond Smart: Exploring the Shift from "Smartness" to True" Intelligence" in Contemporary Housing*

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Abstract

Problem statement: In recent years, the concept of smart homes (SHs) has evolved through advances in digital technology. Yet, many SHs prioritize automation and efficiency over more complex aspects of intelligence, such as learning, adaptability, and meaningful interaction.

Research objective: The main aim of this study is to examine how smartness differs from true intelligence within the realm of contemporary housing. This study analyzes three housing projects to examine the balance between technological innovation and human-centered design, exploring pathways toward achieving "true intelligence" in homes.

Research method: This paper distinguishes between "smartness" and "true intelligence" in housing through a comparative analysis of three global projects: Babcock Ranch (USA), Bosco Verticale (Italy), and Masdar Housing (UAE). The research adopts a comparative analytical framework informed by Howard Gardner's theory of multiple intelligences, while also incorporating evaluations of human, collective, and artificial (AI) forms of intelligence.

Conclusion: Radar chart analysis reveals that Babcock Ranch performs consistently well across all dimensions, particularly in human and collective intelligences, due to its civic platforms and adaptive systems. Bosco Verticale excels in biophilic and spatial design but lacks digital responsiveness. Masdar Housing shows strength in AI-driven and environmental adaptation, yet falls short in user feedback and expressive interaction. The study introduces a novel evaluation framework grounded in Gardner's theory of Multiple Intelligences to assess how housing environments can support cognitive, social, spatial, and existential intelligences. It highlights the need for future designs to go beyond mere smartness toward more human-centered, integrated, and intelligent living environments.

Keywords: *Smartness, Intelligence, Human intelligence, Smart home, Technology.*

Introduction and Problem Statement

In the era of rapid technological advancements, the concept of smart homes (SHs) has captured significant attention, primarily due to their promise of enhancing convenience, energy efficiency, and overall quality of living (Aldrich, 2003; Marikyan et al., 2019; Ahmed et al., 2023). However, while SHs have become increasingly prevalent, there is a growing concern that these homes, though equipped with state-of-the-art automation and technology, which themselves are not considered perfect solutions (Reinisch et al., 2010; Zaidan & Zaidan, 2020, 157), often fall short of achieving true intelligence. True intelligence in housing goes beyond automation; it involves adaptive, learning, and responsive environments that not only

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react to human needs and improve through real-world user feedback but also anticipate them in a meaningful way (Bregman, 2010, 45). In recent years, the term “smart” has become synonymous with any technology featuring some level of artificial intelligence (AI) (Chakraborty, 2024). However, a deeper understanding of intelligence reveals a more nuanced picture, highlighting how different types- human, artificial, and collective (Komninos, 2006; Peeters et al., 2021)- contribute to shaping smarter, more responsive living environments.

The distinction between smartness and true intelligence in housing is critical (Taylor et al., 2007, 392) as the world moves toward more integrated, sustainable, and human-centered living spaces (Ghaffarianhoseini et al., 2013). While numerous projects across the globe are pushing the boundaries of what homes can do, the question remains: can these homes truly understand and adapt to the complexities of human life, or are they merely reacting to pre-programmed commands? This paper seeks to address this gap by examining the evolution of housing from being merely smart to genuinely intelligent. It focuses on three globally recognized housing initiatives: Babcock Ranch (USA), Bosco Verticale (Italy), and Masdar City Housing (United Arab Emirates), each of which represents a distinct approach to integrating technology, sustainability, and human-centered design in contemporary living environments. These projects were selected for their conceptual ambition, technological innovation, and relevance to the evolving discourse on intelligent homes. By analyzing how these cases incorporate both advanced technologies and human-centric intelligence, the study aims to shed light on the future trajectory of housing design.

The primary objectives of this study are then to explore the differences between smartness and true intelligence in the context of contemporary housing, to conduct a comparative analysis of three prominent housing projects, examining how they balance technological innovation with human-centered design & to identify the challenges and opportunities in designing homes that are not only smart but truly intelligent. In this regard, the research questions guiding this study are: What are the key differences between SHs and truly intelligent homes? How do the selected housing projects exemplify or fail to embody true intelligence? Finally, what implications do these differences have for the future of housing design and technology?

Theoretical Background and Literature Review: Intelligence in Contemporary Housing

The growing interest in AI has reshaped both academic and practical conversations, particularly as AI technologies become integrated into everyday environments, including urban and housing systems. Databases such as Google Scholar, Scopus, and Web of Science reflect a significant rise in related publications, underscoring the relevance of these discussions across disciplines. Alongside AI, collective intelligence (CI), where groups collaborate in ways that surpass individual decision-making, has gained prominence, particularly in urban planning and smart housing (SH), where adaptability and user participation are key. Recent interdisciplinary research, from psychology and computer science to urban studies, highlights that intelligence operates on multiple scales: human, artificial, and collective. Understanding their interplay is critical for designing sustainable, responsive, and human-centered housing. Google Trends (2025) reveals that interest in AI has surged since 2022, especially in Vietnam, Ethiopia, South Korea, the Philippines, and Nepal (Fig. 1). CI has shown steady interest, with peaks in South Korea, Réunion, France, and Morocco, contexts known for participatory governance (Fig. 2). Meanwhile, human intelligence (HI) showed early prominence in 2004, declined, and then resurged around 2016, particularly in Ethiopia, Zimbabwe, Zambia, Kenya, and the Philippines (Fig. 3). These variations reflect differing global priorities. While AI dominates in high-tech regions, HI and CI remain central in contexts focused on education, cognition, and community. In the context of SH, these three forms of intelligence offer a useful lens for evaluating how housing can move beyond being merely smart toward becoming truly intelligent.

AI has reshaped how we define and apply the notion of intelligence, particularly through its capacity to perform tasks traditionally requiring human cognition. Central to

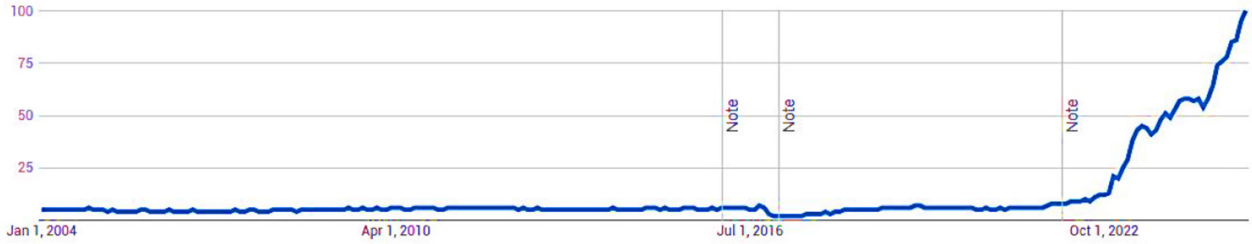

Fig. 1. Trends in "Artificial Intelligence" Interest (2004-2025)- Field of Study, Source: Google Trends , Retrieved April 28, 2025.

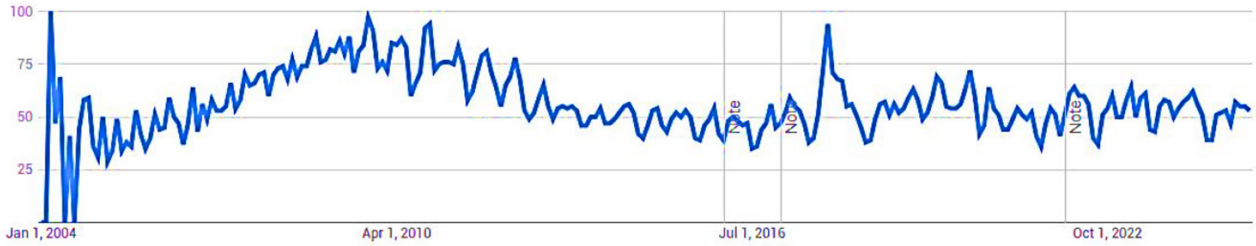

Fig. 2. Trends in "Collective Intelligence" Interest (2004-2025) - Topic, Source: Google Trends , Retrieved April 28, 2025.

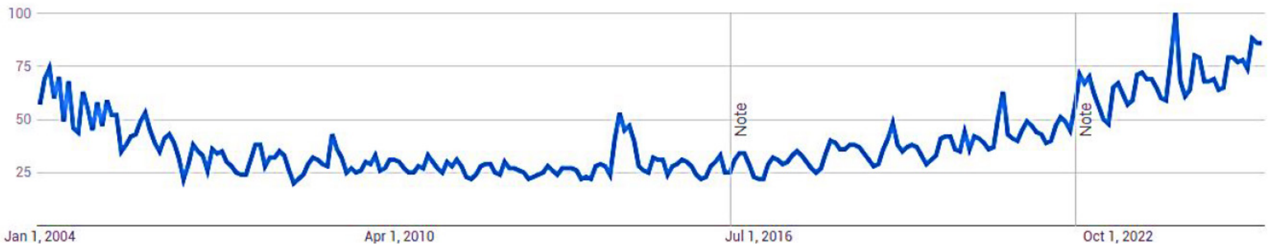

Fig. 3. Trends in "Human Intelligence" Interest (2004-2025) - Search Item, Source: Google Trends , Retrieved April 28, 2025.

this discourse is the distinction between weak AI, which serves as a problem-solving tool, and strong AI, which aspires to emulate true consciousness (Searle, 1980; Flowers, 2019). Core technologies such as machine learning, natural language processing, and neural networks have brought AI into practical use across various domains, prompting critical debates about its ability to replicate, complement, or surpass human intelligence (Korteling et al., 2021). Ethical concerns, ranging from agency to bias, further complicate its integration.

According to the Oxford Dictionary (Intelligence, n.d.), intelligence entails "the ability to learn, understand and think in a logical way about things; the ability to do this well." This definition applies not only to individuals (human intelligence, HI) but also to artificial systems and collectives. AI, defined by Oxford Languages, emphasizes computational capabilities such as perception and decision-making. In contrast, HI encompasses reasoning, learning, and creativity, while collective intelligence (CI) is often framed in scholarly work as a group's capacity to solve problems collaboratively, even without close interpersonal ties (Chikersal et al., 2017). Meanwhile, HI is sometimes narrowly defined in intelligence studies as data gathered through interpersonal contact (Gooch & Williams, 2015), highlighting a tendency to prioritize AI in both academic and public discourse while underdefining human and collective counterparts. However, recent trends in network science have deepened the conceptualization of CI. Centola (2022) notes that while networks can enhance group cognition, they may also distort it, pointing to unresolved theoretical challenges. Similarly, Galesic et al. (2023) explored how dynamic social interactions influence problem-solving, adaptation, and the risk of collective failure. Calling for transdisciplinary approaches to enhance the effectiveness of adaptive collectives.

From Čapek's (1920) early conception of robots to IBM's initial systems (1979-1984) and Engelberger's (1989) vision of service robots (Ruiz-Vanoye et al., 2024), AI's industrial evolution has expanded into everyday life. Though robots may not replicate human consciousness, they increasingly perform complex, real-world tasks with remarkable speed and precision (Cappuccio et al, 2020). The adoption of AI in industrial robotics opens up significant possibilities for enhancing manufacturing processes by leveraging various forms of intelligence, as outlined in Gardner's theory (Fig. 4). These developments underscore how artificial systems, by drawing on logical-mathematical, spatial, and interpersonal intelligences, are transforming not only production processes but also the fabric of intelligent environments, including housing. Understanding these layered intelligences provides a foundation for evaluating whether SHs today are evolving toward true intelligence or merely reinforcing mechanistic responsiveness.

In reference to Fig. 5, AI and CI are tools that represent or extend parts of reality, but they fall short of encompassing the full dimensions of HI, especially intrapersonal, interpersonal, bodily, and existential intelligences (Table 1). This limitation sharpens the boundary between reality and vitality in architecture, daily life, and decision-making. CI emerges through social networks, recommendation systems, and online interactions. While it can be effective in decision-making, ideation, and problem-solving, it may drift away from objective reality and human quality as it is more rooted in virtual space than in lived experience.

In the context of SHs, one can view these spaces as liminal zones where multiple forms of intelligence coexist. HI, embodied, emotional, and multifaceted, interacts with AI, driven by logic and data, as well as CI, emerging through networked collaboration. However, despite the seamless integration of these intelligences, certain deeply human dimensions, such as existential creativity, profound emotions, or physical interaction with the world, remain either absent or merely simulated. This creates a paradox where the house becomes both a site of advanced technological interaction and a space that highlights the absence of certain essential human experiences.

Every type of intelligence requires a spatial and perceptual environment to manifest and operate. Conversely, each form of reality or space activates, enables, or constrains particular types of intelligence (Table 2). Augmented reality (AR) provides a platform for the coexistence and synergy of all three types of intelligence, as it maintains a tangible connection to the physical world. Carmigniani & Furht (2011) define AR as a real-time view of a physical environment, enhanced with computer-generated information. AR is interactive, 3D-registered, and integrates real and virtual elements. Virtual reality (VR) primarily empowers AI and CI, often reducing HI to data streams or avatar-based representations.

AR enhances the user's perception and interaction with the real world by superimposing virtual objects and cues upon it in real time. Unlike VR, which completely immerses users in a synthetic world, as Milgram & Kishino (1994) refer to it as a Virtual Environment, AR technology augments the sense of reality by blending real and virtual elements. As Azuma et al. (2001) explain, AR is not restricted to any specific display technologies, such as head-mounted displays (HMDs), nor is it limited to the sense of sight. It can potentially augment all senses, including smell, touch, and hearing. AR can also be used for sensory substitution, helping users with missing senses. For example, it can use audio cues to augment sight for the visually impaired or visual cues to augment hearing for the deaf (Carmigniani & Furht, 2011). It is worth mentioning here that while classical accounts recognize only the five traditional senses, contemporary research highlights additional internal and crossmodal senses such as balance, proprioception, and pain

Gardner's Multiple Intelligences

Linguistic. Ability to understand and use spoken and written communication. Ideal vocation: poet.
Logical-mathematical. Ability to understand and use logic and numerical symbols, and operations. Ideal vocation: computer programmer.
Musical. Ability to understand and use such concepts as rhythm, pitch, melody, and harmony. Ideal vocation: composer.
Spatial. Ability to orient and manipulate three-dimensional space. Ideal vocation: architect.
Bodily-kinesthetic. Ability to coordinate physical movement. Ideal vocation: athlete.
Naturalistic. Ability to distinguish and categorize objects or phenomena in nature. Ideal vocation: zoologist.
Interpersonal. Ability to understand and interact effectively with other people. Ideal vocation: politician; salesperson.
Intrapersonal. Ability to understand and use one's thoughts, feelings, preferences, and interests. Ideal vocation: autobiographer; entrepreneur. (Although high intrapersonal intelligence should help in almost any job because of its role in self-regulation, few paid positions reward a person solely for knowing himself or herself well.)
Existential. Ability to contemplate phenomena or questions beyond sensory data, such as the infinite and infinitesimal. Ideal vocation: cosmologist; philosopher.

Fig. 4. Gardner's multiple intelligences. Source: Authors based on Moran et al., 2006; Gardner, 2006.

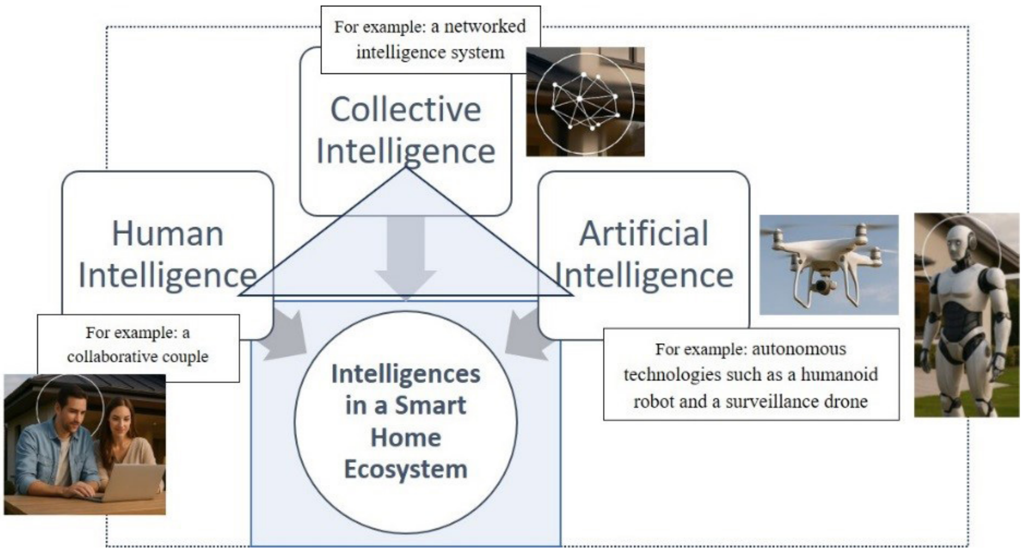

Fig. 5. The convergence of intelligences in a smart home ecosystem. Source: Authors.

Table 1. Artificial intelligence and the limits of human cognition: A Gardnerian perspective. Source: Authors.

Type of HI	AI's Ability to Simulate	Description
Linguistic	High	GPT models and natural language processing tools
Logical-Mathematical	High	Algorithms, problem-solving capabilities
Spatial	Medium	Robotics, design, image recognition
Musical	Medium	Music generation, sound analysis
Bodily- Kinesthetic	Low	Presents in advanced robotics and lacks human flexibility
Interpersonal	Weak	Limited understanding of emotions and relationships
Intrapersonal	Very Weak	Self-awareness, reflection, existential experience
Naturalistic	Low	An intuitive connection with nature is not replicable
Existential	Almost Zero	Questions of meaning, death, and purpose

Table 2. Mapping intelligence across realities. Source: Authors.

Type of Reality	Type of Intelligence It Primarily Activates or Constrains: The cause
Physical Reality	Human Intelligence: Because it is embodied, emotional, and context-based
Augmented Reality	A combination of intelligences: Because it connects physical space with digital layers
Virtual Reality	Artificial + Collective Intelligence: Because it is fully data-driven, simulated, and decontextualized

(Wilson & Macpherson, 2018), underscoring that human perception extends well beyond the traditional five and should be considered in smart and augmented environments.

To critically assess the nature of intelligence in contemporary housing projects, there is a need for a multi-layered and integrative model. One that moves beyond technological determinism and incorporates the human, collective, and cognitive dimensions of spatial experience. The conceptual model developed here identifies three key sources of intelligence: HI, AI, and CI, while also accounting for the perceptual layer of spatial reality and a set of functional-behavioral indicators. Drawing on Gardner's theory of multiple intelligences, this model explores how various forms of intelligence are manifested and embedded within residential environments. The following section presents the conceptual framework (Fig. 6). This model maps the three primary sources of intelligence in contemporary housing in relation to behavioral and functional indicators. These indicators represent both the expression of intelligence in space and a mediating layer between its source and the type of reality in which it is experienced. Given that spatial experiences can occur across physical, augmented (AR), and virtual (VR) environments, the model includes Reality Type as a contextual perceptual layer. While 'Reality Type' is not a form of intelligence itself, it shapes how intelligence is experienced and situated in space. Therefore, incorporating this dimension is essential to understanding how intelligence functions across different

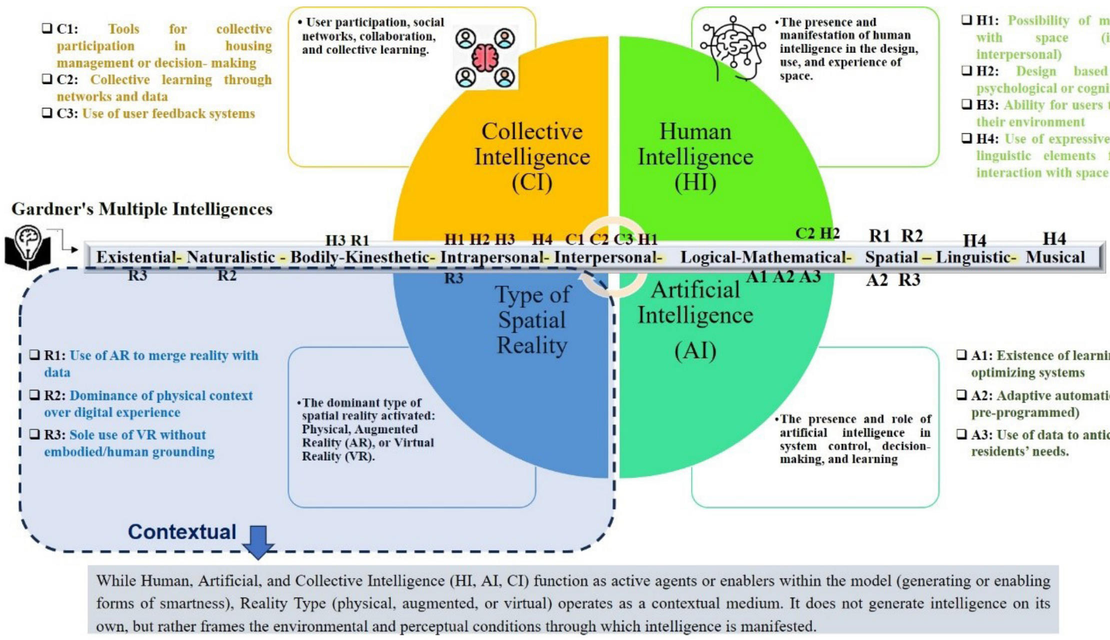

Fig. 6. A multi-layered conceptual model of intelligence in Contemporary housing. Source: Authors.

spatial modalities. To ground the indicators in a human-centered theoretical framework, the model draws on Howard Gardner's theory of Multiple Intelligences. The nine intelligence types proposed by Gardner form the central axis of the diagram, and each indicator is mapped to one or more of these types. This approach offers a more nuanced perspective that moves beyond techno-centric notions of smartness, highlighting instead the cognitive, embodied, and socio-emotional dimensions of intelligent housing.

The indicators used in this study (Table 3) were not directly applied in previous research but are conceptually grounded in established theories across environmental psychology, neuroscience, and biophilic design. Given the lack of prior work integrating various forms of intelligence (human, collective, and artificial) and the realities they engage with, whether augmented, virtual, or physical, this study aims to operationalize such concepts through a set of evaluative indicators. These indicators are designed to enable a structured comparison of selected contemporary smart housing projects. While not explicitly drawn from earlier frameworks, they are interpreted and applied through the lens of the aforementioned theoretical foundations. Recent neuroscientific research has shown that architectural features such as contour influence aesthetic judgment and emotional engagement with space. In particular, curvilinear environments activate brain regions linked to reward and emotional salience (Vartanian et al., 2013), indicating that design can shape meaningful cognitive-emotional interactions between users and built environments. Environmental psychologists emphasize that architecture acts as a physical medium that shapes behavior, emotional responses, and social interaction. Elements such as light, color, proportion, and spatial cues influence users' psychological engagement and can reinforce meaningful experiences in space (Harrouk, 2020). Environmental psychology suggests that our built surroundings have a direct impact on mental health and cognitive performance. Environmental factors such as light, noise, air quality, and spatial layout can affect stress, emotion, and even neural pathways, reinforcing the importance of psychologically informed design in housing (Lindberg, 2025). The Biophilia Hypothesis proposes that humans possess an innate emotional connection to the natural environment. This intrinsic bond supports the idea that spaces allowing meaningful interaction with natural elements (such as vegetation, water, or lifelike structures) can enrich cognitive and emotional experiences within built environments (Kellert & Wilson, 1995). Exposure to biophilic design elements in residential settings significantly enhances physiological comfort and stress recovery, demonstrating that meaningful interaction with natural spatial cues can support psychological and

Table 3 . Integrated framework of intelligence dimensions in Contemporary housing (Note: While they are grounded in existing literature on smart and intelligent housing, the specific operationalization presented here is original and not adopted verbatim from any previous study. The framework is therefore intended as a structured, authors-proposed analytical tool that can be refined or expanded in future research.). Source: Authors.

Intelligence Type	Focus Area	Code	Gardner's Multiple Intelligences	Indicator Description	Source
Human Intelligence (HI)	Cognitive - Experiential	H1	Intrapersonal Interpersonal	Possibility of meaningful human interaction with space	Vartanian et al. (2013), Harrouk (2020), Lindberg (2025), Kellert & Wilson (1995), Al Sayyed & Al-Azhari (2025)
		H2	Intrapersonal Logical-Mathematical	Design based on users' psychological or cognitive needs	Lindberg (2025), Fang et al. (2025), Pulivarthi & Bhatia (2025), Xie et al. (2025)
		H3	Intrapersonal Bodily-Kinesthetic	Ability for users to personalize their environment	Lee & Stuerzlinger (2025), Fabio et al. (2025)
		H4	Interpersonal Linguistic Musical	Use of expressive, auditory, or linguistic elements for cognitive interaction	Pastuszek-Lipińska (2025), Heintz & Scott-Phillips (2023)
Artificial Intelligence (AI)	Systemic-Algorithmic	A1	Logical-Mathematical	Existence of learning and self-optimizing systems	Phiri (2023)
		A2	Spatial Logical-Mathematical	Adaptive automation (beyond pre-programmed routines)	Phiri (2023), Adeel et al. (2014), Okhovat (2023)
		A3	Logical-Mathematical	Use of data to anticipate residents' needs	Phiri (2023), Kaluarachchi (2022)
Collective Intelligence (CI)	Social - Participatory	C1	Interpersonal	Tools for collective participation in housing management or decision-making	Zhou & Lund (2023), Hayes & Murtinho (2023), Yau (2013)
		C2	Interpersonal Logical-Mathematical	Collective learning through networks and data sharing	Akhrif (2022), Wang et al. (2024), Far et al. (2024)
		C3	Interpersonal	Use of user feedback systems	Varlamis et al. (2022), Agee et al. (2021), Ariano et al. (2023)
Type of Spatial Reality	Embodiment - Mediation	R1	Spatial	Use of AR to merge reality with data	Zarzycki (2023), Al-Rimawi & Nadler (2025), Franco et al. (2021)
		R2	Naturalistic Spatial	Dominance of physical context over digital experience	Agee et al. (2021), Kreps (2021)
		R3	Existential Intrapersonal Spatial	Sole use of VR without embodied/ human grounding	Dzardanova & Kasapakis (2022), Sarkady et al. (2021)

emotional well-being (Al Sayyed & Al-Azhari, 2025). These studies provide the theoretical foundation for Indicator H1, which aims to assess the depth of cognitive and emotional interaction fostered by spatial and environmental design features in smart housing.

Adaptive interface designs that account for individual differences in spatial cognitive abilities, such as mental rotation and perspective-taking, can significantly reduce cognitive load and improve human-machine interaction performance (Fang et al., 2025). The effectiveness of graphic representations in enhancing awareness is significantly mediated by individuals' cognitive needs, suggesting that psychological model-based design strategies should be tailored to users' mental processing styles (Xie et al., 2025). Empathy-driven user experience (UX) design highlights the need for emotionally intelligent interfaces that adapt to users' psychological and emotional states, reflecting the growing importance of emotional needs in cognitive-centered design (Pulivarthi & Bhatia, 2025). These findings form the conceptual basis for Indicator H2, which addresses the adaptability of smart housing to users' diverse cognitive capacities and emotional states through interface and interaction design.

Adaptive Extended Reality (XR) navigation interfaces can significantly improve user experience by accounting for differences in spatial abilities and navigation strategies, suggesting that personalization enhances both usability and inclusivity (Lee & Stuerzlinger, 2025). Adaptive user interfaces in Industry 4.0 settings can dynamically support human operators by tailoring digital assistance to evolving skills and contextual demands, reinforcing human-machine symbiosis (Fabio et al., 2025). These insights conceptually support Indicator H3, which emphasizes the ability of users to personalize smart residential environments based on their physical interactions, spatial behaviors, and evolving cognitive needs. This personalization aligns with bodily-kinesthetic and intrapersonal intelligences, enabling more intuitive and meaningful engagements with space.

Music, through its multisensory and affective properties, plays a pivotal role in shaping linguistic, emotional, and cognitive functions, offering insights for the design of interfaces that support communication and mental well-being (Pastuszek-Lipińska, 2025). Human expression spans diverse modalities: language, gesture, art, and social interaction, all driven by evolved cognitive capacities for conveying and interpreting informative intentions. These capacities form the foundation of affective and multisensory communication, providing critical insights for the design of expressive human-machine interfaces (Heintz & Scott-Phillips, 2023). These insights support Indicator H4, which focuses on integrating expressive, auditory, and linguistic components into SH interfaces to enhance cognitive interaction and improve social and emotional engagement with the built environment.

Computing has evolved from static to self-managing, adaptive systems that can autonomously optimize resources, reflecting the increasing complexity of modern challenges (Phiri, 2023). This evolution is central to Indicators A1, A2, and A3, which focus on self-optimizing systems, adaptive automation, and data-driven approaches to anticipate and meet residents' needs in SH. Adeel et al. (2014) discuss a self-adapting networking scheme that dynamically chooses between short-range opportunistic transmissions and long-range cellular radios to optimize network throughput and costs. This demonstrates adaptive automation in communication strategies beyond fixed routines. The scheme's ability to adapt its communication strategy based on current network conditions exemplifies adaptive automation beyond pre-programmed routines, as described in the A2 indicator. Okhovat (2023) describes a policy-based autonomic management system that continuously monitors and analyzes data to optimize urban operations automatically, exemplifying adaptive automation beyond pre-programmed routines, supporting A2. Kaluarachchi (2022) discusses how real-time data promotes citizen participation and helps urban systems respond proactively, emphasizing the use of real-time data to improve urban services, forecast future scenarios, and enhance citizen participation, which aligns with using data to anticipate and meet residents' needs, supporting the A3 indicator. Batty (2013) shows how urban big data, especially streaming sensor data and smart travel card data, is shifting city management toward short-term, anticipatory decision-making, exemplifying data-driven approaches to meet residents' needs (reinforcing A3).

C1 indicator reflects the tools enabling collective participation in housing management. Yau (2013) shows that despite rational disincentives, some homeowners in multi-owned housing engage in collective action, highlighting the need for participatory mechanisms that support the perceived efficacy and benefits of involvement. Additionally, Hayes & Murtinho (2023) show that participatory mechanisms significantly shape household involvement in communal processes, and inclusive communal decision-making depends on governance tools such as frequent meetings and leadership training. In more technology-driven contexts, Peer-to-Peer (P2P) platforms for energy sharing (Zhou & Lund, 2023) illustrate how digital infrastructures can enable fair and dynamic collective decision-making. These findings collectively underscore the role of participatory tools, whether institutional or technological, in enabling fair and sustained engagement (C1). Regarding C2, in smart urban ecosystems, the concept of "Housing-as-a-learning-platform" emphasizes that intelligent housing should not only integrate technology but also foster collective learning through data sharing and networked interactions among residents. Drawing on the Smart University model (Akhrif, 2022), where intelligent learning and interdisciplinary collaboration are enabled by digital infrastructure, SH can likewise benefit from embedded systems that support adaptive, participatory, and data-driven learning processes. Smart communities build neuron-like data collection networks across multiple spatial levels (street, neighborhood, household), enabling real-time information sharing and adaptive services (Wang et al., 2024). This aligns with the core of collective learning in intelligent housing, where shared data flows and digital infrastructures support responsive, participatory living environments. Far et al. (2024) explore the integration of blockchain and deep reinforcement learning (DRL) in IoT networks, demonstrating how decentralized systems can improve privacy, security, and data sharing in smart cities. By enabling efficient mobile transmission and secure data exchange, these technologies enhance collective learning within interconnected, data-driven environments. The study's interdisciplinary approach provides insights into how collaborative networks, supported by cutting-edge technologies, can advance the adaptability and efficiency of IoT systems (which can be used in SH).

Agee et al. (2021) emphasize the importance of integrating user feedback systems in the design of smart buildings. By collecting data from occupant surveys, energy usage, and interviews, the research adopts a human-centered approach, utilizing feedback to inform the design process. This iterative feedback loop ensures that smart building systems align more closely with the actual needs and preferences of the occupants, maximizing both well-being and operational performance. Ariano et al. (2023) emphasize improving user engagement in smart environment automation by incorporating dynamic, context-sensitive, and augmented reality-based representations. By allowing end-users to interact with connected sensors and objects through their smartphones and receive immediate feedback, this approach actively involves users in defining and modifying their environment's automations. The positive feedback from the initial user test demonstrates the effectiveness of this user-centered design, which aligns well with the concept of user feedback systems in smart environments. Varlamis et al. (2022) present an online recommender system that integrates user feedback to optimize energy-saving behaviors in smart environments. The system fuses sensor data with user habits and feedback, providing personalized energy-saving recommendations. The continuous evaluation of user responses helps refine future suggestions, ensuring that recommendations are timely and effective, aligning well with the concept of user feedback systems to enhance decision-making and improve user engagement (C^3 indicator).

Zarzycki (2023) explores the integration of augmented reality (AR) with Internet of Things (IoT) technologies in the built environment, particularly in construction, building use, and facility management. The synergy between AR and IoT not only enhances the visualization of real-time environmental data but also allows for active control of building systems in a user-specific context. By merging physical and virtual assets through AR overlays, this approach significantly enhances spatial interaction and provides a more intuitive interface for users. Al-Rimawi & Nadler (2025) highlight the role of data sharing and collective learning in utilizing smart technologies for real estate development. The integration of Big Data, GIS, and AI enables stakeholders to collaboratively share knowledge, improving decision-making and creating smarter cities and real estate. Franco et al. (2021) explore appliance load monitoring in SHs using both intrusive load monitoring (ILM) and non-intrusive load monitoring (NILM) methods, proposing a novel IoT-based activity recognition system. Data is processed through various layers of the architecture, and three machine learning models: feed-forward neural network (FFNN), long short-term memory (LSTM), and support vector machine (SVM), are tested to predict daily activities based on appliance usage patterns. Regarding AR, this approach could be used to merge data with reality in SHs, allowing users to interactively view energy consumption and activities (R^1 indicator).

Agee et al. (2021), through their human-centered approach to smart home (SH) design, emphasize the dominance of physical context, such as user needs and behaviors in real-world spaces, over digital experiences, aligning with indicator R^2 indicator. Kreps (2021), in a book chapter, introduces the concept of "infomateriality" to highlight how digital tools and information exchanges are increasingly embedded within the physical context of everyday life, blurring the lines between the digital and the material. This concept resonates with the R^2 indicator.

As Kreps claims, the digital experience is not conceived in isolation but rather defined within and influenced by the physical and material context; therefore, there is a philosophical emphasis on the precedence and dominance of the physical environment over digital experiences.

Regarding the framework of the R^3 indicator, Pustejovsky & Krishnaswamy (2021) argue that VR systems lacking embodied or human grounding are insufficient for meaningful HCI. They introduce VoxWorld, a simulation platform that creates embodied, context-aware virtual interactions by placing both human and artificial agents within the same simulated environment, enabling shared perception and understanding. Unlike this study, Dzardanova & Kasapakis (2022) reject the idea of VR as striving toward an "ultimate display" and instead trace how VR experiences have gradually evolved, often detached from physical embodiment, to become commoditized digital environments. Sarkady et al. (2021) examine the role of Virtual Reality (VR) as a substitute for physical travel during the COVID-19 pandemic, where VR is used in isolation without the need for physical presence or embodied experience. The findings emphasize VR's potential as a tool for creating virtual travel experiences, where users engage with the virtual environment without the need for physical presence, effectively substituting actual travel during periods of instability.

Research Method

This study employed a comparative analytical approach grounded in Howard Gardner's theory of multiple intelligences, alongside assessments of human, collective, and artificial intelligence (AI). The research focused on evaluating three iconic housing projects: Babcock Ranch (USA), Bosco Verticale (Italy), and Masdar City Housing (United Arab Emirates). By examining how their technological features aligned with various types of intelligence and different realities, including augmented, virtual, and physical environments, this study attempted to provide insights into their effectiveness. Data collection involved desk-based analysis of published materials, including project designs, technological implementations, and user interactions. The evaluation criteria were based on the extent to which these housing models showed true intelligence, such as adaptability, learning capacity, and meaningful interaction. The comparative analysis aims to identify gaps and the potential for integrating advanced intelligent features in contemporary housing. The indicators in this framework were not arbitrarily selected. They emerged through a theory-informed conceptual synthesis based on four distinct but interrelated dimensions of "intelligence" in the context of contemporary housing:

- **Human Intelligence (HI):** Rooted in theories of cognitive psychology and environmental psychology, these indicators capture how humans perceive, engage with, and cognitively relate to space. Sources include theories by Howard Gardner (Multiple Intelligences), environmental cognition, and spatial personalization literature.
- **Artificial Intelligence (AI):** Derived from literature on smart homes (SHs), ambient intelligence, and machine learning in architecture, these indicators reflect how systems can learn, adapt, and act on behalf of users, going beyond simple automation.
- **Collective Intelligence (CI):** Based on concepts from participatory design, urban sociology, and platform-based governance, these indicators examine how housing environments support group learning, community feedback, and co-management.
- **Spatial Reality Type:** Developed from media theory, XR/VR studies, and architectural embodiment, these indicators classify the dominant mode of spatial mediation (physical, AR-enhanced, or fully virtual).

Each group of indicators was formulated to allow for cross-project comparison while remaining sensitive to the specific roles of technology, cognition, and community in shaping "intelligent" housing. Together, they build a multidimensional model for evaluating the transition from "smart" to truly intelligent living environments. To deepen the cognitive basis of the framework, each indicator is mapped to Gardner's Multiple Intelligences.

- **Intrapersonal Intelligence:** the ability to understand one's own emotions, needs, and inner states. This is reflected in indicators such as H1, H2, and H3, where the space supports self-awareness, personal expression, and cognitive well-being.
- **Interpersonal Intelligence:** the capacity to understand and interact effectively with others. This is tied to H1,

H4, and all CI indicators (C1-C3), emphasizing social interaction, collaboration, and feedback.

- Logical-Mathematical Intelligence: linked to analytical thinking and system-based reasoning. It underpins most AI indicators (A1-A3) and some CI indicators (such as C2), demonstrating how systems reason, learn, and predict.

- Linguistic and Musical Intelligence: found in H4, where cognitive interaction with space may occur through expressive language, sound, or auditory cues, fostering more engaging environments.

- Bodily-Kinesthetic Intelligence: involved in the user's ability to physically personalize or modify their environment, as seen in H3.

- Spatial Intelligence: the capacity to think in three dimensions. It appears in A2 (spatial adaptation), R1-R3 (engagement with physical, AR, or VR environments), and supports the sensory navigation of space.

- Naturalistic Intelligence: the ability to perceive and interact with natural patterns and environments. This is considered in R2, where the dominance of physical (often ecological) experiences is evaluated, particularly relevant to biophilic or nature-integrated designs like Bosco Verticale.

- Existential Intelligence: (an often debated "ninth" intelligence) - appears in R3, linked to the philosophical and embodied implications of inhabiting virtual spaces with or without grounding in human presence.

This mapping ensures that the framework captures not only technological performance but also diverse HIs involved in inhabiting and co-creating intelligent living environments.

Case Study

To comparatively examine the presence and interplay of different forms of intelligence (human, artificial, and collective) across diverse technological and spatial realities, three exemplary smart housing (SH) projects have been selected:

- **Babcock Ranch (Florida, USA) (2015- 2035)**

Babcock Ranch exemplifies a next-generation smart housing model rooted in environmental stewardship and technological integration. With 50% of its land dedicated to green spaces and 90% developed on previously impacted terrain, the community is designed around restoration, sustainability, and ecological resilience. Homes are constructed to Florida Green Building standards, while water conservation is embedded through native landscaping and eco-hydrological systems like the Curry Lake Preserve. Social interaction and collective learning are promoted via community gardens, parks, and digital infrastructure, positioning Babcock Ranch as a living lab for intelligent, nature-integrated urban living (Babcock Ranch, 2025). As shown in (Fig. 7), the community integrates extensive green spaces, ecological restoration, and smart infrastructure, exemplifying sustainable and nature-integrated urban living.

- **Bosco Verticale (Milan, Italy) (2007 - 2014)**

This vertical forest model, recognized as Stefano Boeri Architetti's signature, embeds biophilic design and ecological intelligence within high-density urban housing (Commission: Residential towers). Its integration of vegetation and responsive environmental systems creates a living façade, allowing for human-nature interaction, while also utilizing digital systems for monitoring and maintenance (Vertical Forest, n.d.; Giacomello & Valagussa, 2015). The residential towers (Fig. 8) feature vertical greenery that promotes human-nature interaction while integrating environmental monitoring systems.

- **Masdar Housing (Masdar City, UAE)**

As part of a larger smart city vision, Masdar's residential units emphasize sustainable automation, AR-enhanced interfaces, and community-level energy optimization. The project is notable for its attempt to balance technological autonomy with collective ecological awareness. It embraces modern living while making a positive impact on the planet. Masdar City's residential community offers energy- and water-efficient design, smart technologies, green parks, and convenient amenities (Sustainability at Masdar City, n.d.; El-Aby, 2017; Kumar, 2022). Accordingly, Fig. 9 shows the residential units integrate smart technologies, energy- and water-efficient design, and communal green spaces, supporting sustainable and technologically-enabled living.

These cases represent diverse geographies and design ideologies, offering a rich basis for comparing how SH prototypes embody or diverge from different forms of intelligence and the realities (virtual, augmented, or physical) they prioritize. The cases' diversity strengthens the analytical validity of the study by allowing cross-case verification of patterns and divergences, while the comparative depth supports interpretive reliability.

Results

This section presents the comparative findings of the three selected housing projects based on the proposed multi-intelligence framework. Through a series of evaluative tables, each project is analyzed across key dimensions: HI (Table 4), CI (Table 5), AI (Table 6), and Spatial-Environmental Reality Typologies (Table 7). The synthesized radar chart (Fig.10) at the end offers a visual summary of how each development embodies or lacks aspects of true intelligence beyond conventional smartness. The ecological findings related to artificial canals at Babcock Ranch illustrate the potential for environmental personalization, as landscape interventions respond dynamically to ecological data and native species resilience (Ceilley et al., 2013). The community's ability to maintain critical services during Hurricane Ian highlights the effectiveness of cognitive and environmentally responsive design strategies at Babcock Ranch, including eco-friendly construction and adaptive water management (Cifrino & Perez, 2024). In Bosco Verticale's neighborhood, residents responded to exclusive top-down greening with the creation of a public community garden, demonstrating a form of environmental personalization and grassroots interaction (Di Paola, 2021) that reflects key aspects of human intelligence in urban space. Bosco Verticale contributes to a meaningful urban experience, as shown by research into the daily spatial practices and lived interactions of its residents and visitors (Visser, 2019). Such green architecture can enhance personal and interpersonal connections to space, especially when inclusive access is supported. Kalogeropoulos et al. (2024) show how

Fig. 7. Babcock Ranch (Florida, USA). Source: Authors based on www.openstreetmap.org; Babcock Ranch, 2025.

Fig. 8 . Bosco Verticale (Milan, Italy). Source: Authors based on Stefano Boeri Architetti, 2025; www.openstreetmap.org.

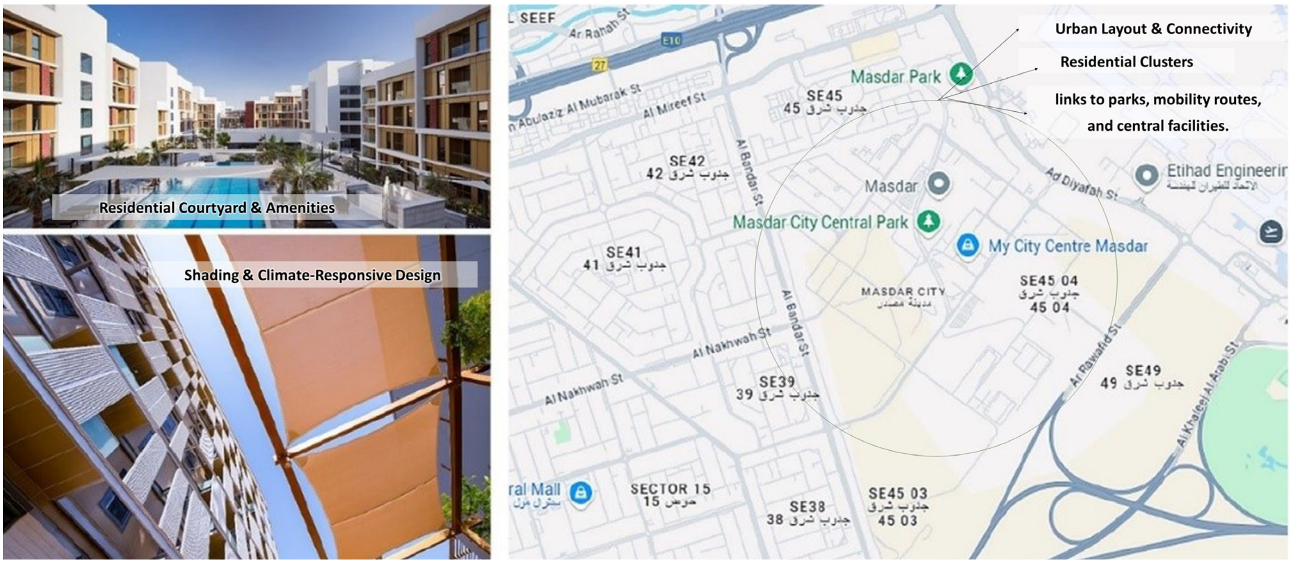

Fig. 9. Masdar Housing (Masdar City, UAE). Source: Authors based on www.openstreetmap.org; www.masdarcity.ae.

shaded green areas in the Bosco Verticale significantly reduce surface and air temperatures, supporting cognitive and physical comfort for users. The presence of natural versus artificial materials also reveals a strong connection between environmental perception and thermal well-being. The design of Bosco Verticale reflects a high degree of environmental awareness, using vegetation to absorb CO_2, produce oxygen, and mitigate the urban heat island effect (Donderewicz & Zawada, 2023), clear evidence of human intelligence in addressing ecological challenges through architecture.

The importance of “Masdar” is not restricted to constructing one of the most sustainable cities in the world or its appealing lifestyle (H2); it also lies in its ability to achieve that with high economic efficiency. This is accomplished through meticulous planning, design, and operation that employs cutting-edge, economic techniques integrating them into advanced systems capable of reducing the costs and managing (H3) materials consumption (Madakam & Ramaswamy, 2016; El-Aby, 2017; Abou Zahr, 2025). The buildings are oriented to maximize the flow of cool air, especially in the public space under the building, which is especially beneficial in Masdar’s extremely hot climate. Building materials aimed at maximizing energy efficiency and comfort are used throughout the buildings (Madakam & Ramaswamy, 2016).

The evaluation of HI indicators across the three selected housing projects (Table 4) reveals distinct approaches to addressing human-centered interaction within residential environments. Regarding H1, which pertains to the possibility of meaningful interaction, Babcock Ranch and Masdar Housing demonstrate stronger performance, as their spatial design, participatory infrastructure, and emphasis on community engagement support rich social and interpersonal interactions. In contrast, Bosco Verticale focuses more on inward interaction with nature, fostering individual reflection rather than social engagement. For H2, which concerns design based on psychological or cognitive user needs, all three projects incorporate mental comfort as a priority. However, this is more explicitly realized in Babcock Ranch and Bosco Verticale, one through active social and environmental engagement, the other through vertical biophilic design and sensory calm. In terms of H3, or the ability for users to personalize their environment, Babcock and Masdar provide greater flexibility and control, both spatially and technologically, while Bosco’s highly formalized design offers limited personalization options. As for H4, which assesses the use of expressive, auditory, or linguistic elements, none of the projects directly implements these features. Still, indirect expression is partially achieved through architectural form, participatory design, or environmental cues. Overall, Babcock Ranch shows the highest alignment with HI indicators, with a strong focus on social interaction and psychological well-

Table 4. HI Assessment, Source : Authors based on official project documentation and design descriptions, including Vertical Forest, n.d.; Sustainability at Masdar City, n.d.; Ceilley et al., 2013; Madakam & Ramaswamy, 2016; Karayaneva & Coleman, 2017; El-Aby, 2017; Visser, 2019; Di Paola, 2021; Donderewicz & Zawada, 2023; Cifrino & Perez, 2024; Kalogeropoulos et al., 2024; Abou Zahr, 2025; Babcock Ranch, 2025.

Project	H1: Meaningful Interaction (Intrapersonal/ (Interpersonal	H2: Psychological/Cognitive Design	H3: Environmental Personalization	H4: Expressive Auditory, or Linguistic Elements	Overall HI Assessment
Babcock Ranch, Florida	Promotes Community interaction via parks, gardens, trails, and digital platforms fosters stewardship and social learning.	Design encourages resident well-being through green spaces, low-impact materials, and social bonds.	Residents engage with environment via sustainability practices, shared infrastructure, and home energy systems.	No direct auditory/ linguistic systems, but community-based learning and participatory tools reflect cognitive expression.	High (Socially Integrated+ Ecologically Grounded)
	Very High- Strong social and participatory focus	High – Green infrastructure and responsive planning	High - Eco-smart customization options	Low – Minimal expressive interface design	
Bosco Verticale, Milan	Encourages individual connection with nature; residents report psychological benefits from vertical greenery.	Green façade design supports psychological comfort, stress reduction, and cognitive restoration.	Limited smart features, but environmental experience is indirectly personalized through natural immersion.	No direct expressive systems, but poetic architectural language evokes emotional response.	Moderate to High (Nature-Centric HI)
	High – indirect social and nature connected interaction	Moderate – Biophilic response without user-centric tech	Moderate – Some spatial personalization (balconies)	Low – Expressivity mostly visual	
Masdar Housing, UAE	Designs emphasize sustainable living and community interaction through passive and shared cooling spaces	Designed to enhance comfort through climate-sensitive architecture and passive environmental control.	Some adaptability in smart systems is achieved through personalization via energy tracking and environmental control in homes.	Limited direct expression, though environmental design promotes ambient cues and symbolic spatial language.	Moderate (Tech-Environmental Balance)
	Moderate – Some community infrastructure, but centralized	High- Responsive to climate and sustainability	Low to Moderate- less user flexibility	Low – No emphasis on expressive or linguistic interfaces	

being. Bosco Verticale excels in promoting individual mental health through nature integration, while Masdar Housing offers a balanced mix of social engagement, environmental design (Karayaneva & Coleman, 2017), and personalization, though it lacks explicit expressive or auditory interaction systems.

The implementation of IoT in Bosco Verticale enables continuous monitoring of plant health and environmental conditions, optimizing irrigation systems through intelligent automation (Donderewicz & Zawada, 2023). The Masdar City aims to integrate the use of GIS in every aspect to plan the city: from ensuring that the construction process is efficient and produces zero waste to planning the transport and energy networks to meet potential demand, and incorporating monitoring systems into the city's physical infrastructure (Madakam & Ramaswamy, 2016). In the Masdar City project, artificial intelligence (AI) plays a crucial role in shaping sustainable and efficient urban environments. By leveraging AI technologies, the project can analyze large datasets rapidly and accurately, enabling innovative urban design solutions that address human needs and environmental challenges. AI is utilized to automate repetitive tasks, optimize resource management, enhance safety measures, and improve the overall quality of life for residents. The integration of AI-driven tools supports decision-makers in developing smarter infrastructure, promoting sustainability, and ensuring a resilient urban ecosystem. Through these applications, Masdar City exemplifies how artificial intelligence can be effectively embedded into urban planning to create a more livable, environmentally friendly, and innovative urban space (Madakam & Ramaswamy, 2016; Elsakka & Kamer Eldawla, 2024).

Babcock Ranch demonstrates a strong use of data, automation, and learning systems, especially in energy and environmental services, earning consistently high ratings across all AI-related dimensions (Babcock Ranch, 2025). In contrast, Bosco Verticale relies more on passive ecological intelligence rather than advanced technological AI. It scores Moderate across all indicators. Masdar Housing integrates advanced SH features and real-time environmental control, placing it at a High level similar

Table 5. AI assessment. Source: Authors based on official project documentation and design descriptions, including Vertical Forest, n.d.; Sustainability at .Masdar City, n.d.; Madakam & Ramaswamy, 2016; Kumar, 2022; Donderewicz & Zawada, 2023; Elsakka & Kamer Eldawla, 2024; Kalogeropoulos et al., 2024; Babcock Ranch, 2025.

Project	A1: Learning & Self- Optimizing Systems	A2: Adaptive Automation (Beyond Preprogramming)	A3: Use of Data to Anticipate Residents' Needs	Overall AI Assessment
Babcock Ranch, Florida	Babcock Ranch incorporates data-driven systems to optimize energy usage and environmental sustainability, with SHs that adapt to resident needs and learning capabilities. High - SHs & responsive systems optimize energy use and adapt to the user behavior.	The town's infrastructure uses real-time data to adjust services such as lighting, waste management, and energy consumption dynamically, showcasing adaptive automation. High – The project features a dynamic infrastructure for energy, lighting, and waste management.	The use of data from environmental sensors and home energy systems helps predict and respond to residents' needs, such as adjusting the temperature and optimizing the resource use. High - Real-time environmental & residential data anticipate needs.	High (Strong data- driven driven sustainability systems and predictive technologies)
Bosco Verticale, Milan	Bosco Verticale focuses on biophilic design and green architecture, although not primarily self-optimizing, it integrates ecological systems that contribute to energy savings and air quality improvement. Moderate –The current design is characterized by passive ecological systems, limited smart adaptation.	While there is limited direct automation, the environmental design promotes energy efficiency through natural systems, supporting sustainability efforts Moderate - Automation is mostly environmental, not user-driven.	Data on environmental factors (e.g., air quality) and energy use helps adjust building functions, although these systems are not highly advanced in anticipating individual needs. Moderate - Data improves efficiency but lacks predictive depth.	Moderate (Emphasis on ecological systems over technological automation)
Masdar Housing, UAE	Masdar's smart home systems incorporate renewable energy, energy storage, and adaptive learning, which optimize energy use based on residents' patterns and needs. High - Smart systems optimize renewable energy and home conditions.	Adaptive systems in homes allow residents to control and optimize energy use and air quality, showing a significant level of dynamic, context-aware automation. High – Environmental systems adapt to use and climate.	Data from SHs and urban sensors enables predictions related to energy usage, environmental conditions, and residents' comfort needs. High - Sensor data supports the prediction of comfort and use	High (Innovative smart technology and environmental data-driven systems)

to Babcock, though more focused on sustainability and efficiency (Table 5).

Babcock Ranch's coordinated resilience during Hurricane Ian and the transferable lessons it offers for future urban development exemplify systemic preparedness and collective learning in practice (Cifrino & Perez, 2024). In Bosco Verticale's neighborhood, the collective action of local groups in contesting exclusionary green projects and establishing a democratic, community-managed garden exemplifies collective intelligence through participatory urban transformation (Di Paola, 2021). The multiple interpretations of the Bosco Verticale by users and planners (Visser, 2019) reflect a form of collective intelligence, where the co-evolution of expert intent and everyday spatial experience shapes the perceived value of green urban infrastructure. The integration of in-situ measurements, remote sensing, and algorithmic modeling in the Bosco Verticale study (Kalogeropoulos et al., 2024) reflects a distributed, collaborative approach to urban climate intelligence. The one that enables continuous learning and adaptive design in city systems. The integration of Building Information Modeling (BIM) for structural, airflow, and environmental modeling in Bosco Vertical exemplifies collaborative intelligence by bringing together multiple disciplines to achieve sustainable and efficient urban living (Donderewicz & Zawada, 2023). Despite aiming for a sustainable and diverse lifestyle in Masdar City, social participation during planning is often overlooked due to the lack of nearby sustainable communities. Engaging residents through meetings is essential to address their needs and ensure that development aligns with local lifestyles (El-Aby, 2017).

Among the three case studies, Babcock Ranch demonstrates the strongest integration of collective intelligence (CI) principles. It offers multiple tools for community participation, promotes collective learning through interconnected environmental and behavioral data, and features accessible feedback systems via digital platforms, earning it a high to very high score across all indicators. Visioning sessions and negotiations with environmental coalitions illustrate the project's attempt to incorporate collective intelligence early in its design phase (Bernstein, 2006). Babcock Ranch was not merely a private real estate project but also the result of a complex interaction between state-led land preservation strategies and private development ambitions. As the largest acquisition in the history of Florida Forever and Preservation 2000, it reflects broader tensions between environmental preservation and urban growth management in Florida (Higgins & Paradise, 2017). In contrast, Bosco Verticale exhibits minimal collective features. Its focus remains on individual experience and passive environmental benefits, with limited mechanisms for community input or learning, resulting in low scores across most CI indicators. Masdar Housing presents a more balanced but moderate approach. While it integrates some data-driven systems for environmental learning and enables limited resident input, formal tools for collective decision-making are still emerging. Overall, Babcock Ranch reflects a more mature and participatory model of CI, aligning community, technology, and sustainability in a cohesive framework (Table 6).

The assessment of spatial reality across the three housing projects (Table 7) reveals distinct orientations in the integration of physical and digital layers. Bosco Verticale demonstrates a strong emphasis on physical reality, with no use of augmented reality (AR) or virtual reality (VR), and a deeply embodied interaction with nature, reflecting a very high dominance of physical context. Babcock Ranch, while grounded in ecological and social interaction, incorporates moderate digital overlays through dashboards and monitoring systems, though it lacks immersive AR or VR components. In contrast, Masdar Housing presents a balanced blend of digital and physical systems. Its smart infrastructure allows for a semi-augmented experience, though not fully immersive, while still maintaining a tangible, climate-responsive design. Across all projects, disembodied VR systems are either absent or minimal, indicating a broader architectural commitment to embodied and contextual engagement.

The radar chart below (Fig. 10) provides a comparative visualization of three housing projects across four major dimensions of intelligence. Each dimension is assessed based on a set of qualitative subindicators (e.g., H1-H[4] for HI), allowing for a detailed analysis of how each project integrates different aspects of intelligence and reality. A 5-point qualitative scale is used to evaluate each indicator: Very High = 5, High = 4, Moderate = 3, Low = 2, Very Low = 1. This scale enables the transformation of descriptive evaluations into visual, quantitative comparisons suitable for radar chart representation.

Table 6. CI assessment, Source: Authors based on official project documentation and design descriptions, including Vertical Forest, n.d.; Sustainability at Masdar City, n.d.; Bernstein, 2006; Higgins & Paradise, 2017; El-Aby, 2017; Di Paola, 2021; Visser, 2019; Kumar, 2022; Donderewicz& Zawada, 2023; Kalogeropoulos et al., 2024; Babcock Ranch, 2025.

Project	C1: Tools for Collective Participation in Management/ Decision- Making	C2: Collective Learning via Networks & Data	C3:Use of User Feedback Systems	Overall CI Assessment
Babcock Ranch, Florida	Offers resident forums, digital tools, and civic platforms to engage citizens in town planning and sustainability initiatives. Community events encourage cogovernance. High - Digital forums & civic platforms	Infrastructure integrates environmental and behavioral data shared across smart grids and communities for mutual learning. High - Shared smart grid data	Residents can give input through town apps and energy dashboards; feedback loops are integrated in service improvement. High - App-based user feedback	High (Participatory and Data-Driven Collective Intelligence)
Bosco Verticale, Milan	Limited mechanisms for collective governance; decisions are mostly top-town from management. Low to Moderate – Limited resident engagement tools	Environmental data (e.g., from greenery) is collected, but little public interface exists for shared learning. Moderate - environmental cues remain fragmented and not networked	Minimal structured systems for users' feedback; resident experience is individualized. Low - No formal user feedback system	Low to Moderate (Nature-Centered but Weak in Collective Governance)
Masdar Housing, UAE	Some community co-design and sustainability outreach, but governance remains largely centralized Moderate - Some planning input via governance	Smart infrastructure enables shared data on energy and water usage; potential for networked learning exists. Moderate to High - Data-driven environmental systems	Feedback channels exist through apps, but not widely promoted for decision-making. Moderate – Some energy tracking and controls	Moderate (Structured Tech Sharing but Limited Participation)

Table 7. Type of spatial reality assessment. Source: Authors based on official project documentation and design descriptions, including Vertical Forest, n.d.; Sustainability at Masdar City, n.d.; Kumar, 2022; Babcock Ranch, 2025.

Project	R1	R2	R3	Overall Spatial Reality Assessment
Babcock Ranch, Florida	Environmental data is accessible via dashboards and smart systems, but not through immersive AR.	Physical experience and ecological design dominate; the digital layer supports, but does not replace the physical.	VR is not central; all experiences are rooted in the real environment.	Reality enhanced (Ecologically (Grounded
	Moderate - Data visible via dashboards, not immersive	High - real-world design and ecology are prioritized over standardized digital metrics	Very Low - No VR or disembodied tech	
Bosco Verticale, Milan	No AR integration; user experience is mainly passive and physical.	The project is almost entirely about physical immersion in nature, with no digital mediation.	No virtual simulations or detachment from Bosco embodied reality.	Pure Physical (Biophilic Im- (mersion
	Low - No AR elements are used	Very High - Purely physical and nature-based	Very Low - Fully embodied natural experience	
Masdar Housing, UAE	Digital data systems (e.g., energy monitoring) partially inform physical space; some smart interface approach AR-like function.	Although physical climate response is prioritized, digital systems are embedded for optimization.	There is some virtualization, but not without embodied environmental grounding.	Hybrid (Smart Physical Inte- (gration
	Moderate to High – Some interfaces emulate AR-like functionality.	Moderate - Mix of physical and digital layers	Low – Limited virtualization, mostly grounded	

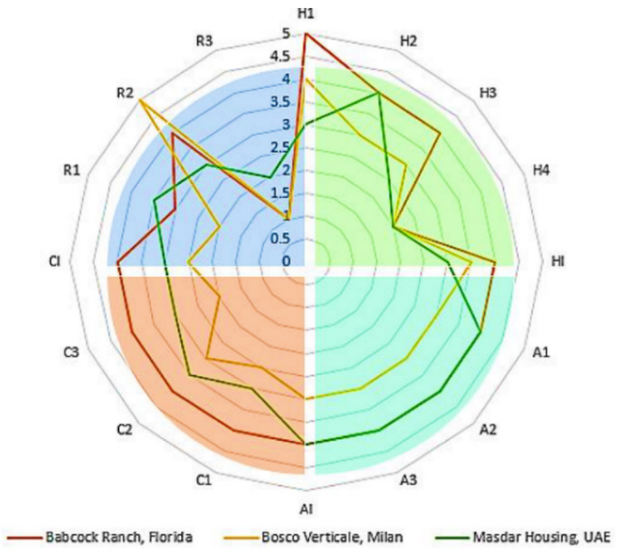

Fig. 10. The radar chart: a comparative visualization of three housing project. Source: Authors.

The radar chart reveals that Babcock Ranch consistently performs well across all intelligence dimensions, particularly in HI and CI, due to its strong social engagement, adaptive systems, and civic participation platforms. It shows moderate engagement with augmented reality but limited use of immersive VR technologies. Bosco Verticale, while highly successful in psychological and biophilic design, scores lower in digital adaptability and CI infrastructure. Its spatial experience is strongly grounded in physical reality and natural interaction, but lacks digital depth. Masdar Housing achieves high scores in AI and climate-responsive design, with moderate performance in human and collective dimensions. It adopts smart technologies effectively but still lacks strong user-driven feedback systems and expressive digital elements.

Discussion

• Integration of multiple intelligences in Contemporary housing

In this analysis, each project's assessment aligns with specific types of intelligence according to Gardner's model. The scores for each project reflect how different intelligences are integrated within the physical and digital design of the spaces. The comparative analysis of intelligence indicators across the three housing projects reveals that Babcock Ranch excels in integrating interpersonal and environmental intelligence through participatory design and smart systems. In contrast, Bosco Verticale reflects a stronger alignment with spatial and naturalistic intelligences, emphasizing biophilic design over communal engagement. Masdar Housing demonstrates a technological-environmental balance, drawing on logical and intrapersonal intelligences but lacking expressive and interpersonal depth.

Human Intelligence Dimensions (H1-H4): Babcock Ranch demonstrates a comprehensive integration of both intrapersonal and interpersonal intelligences (H1) by fostering self-awareness and strong social interaction through community participation and green living. It also excels in psychological and logical design (H2), offering sustainable infrastructure that balances well-being with cognitive clarity. The project supports bodily-kinesthetic engagement (H3) through active outdoor environments, although it remains limited in expressive linguistic or musical elements (H4). Bosco Verticale, in contrast, emphasizes nature-connectedness and psychological restoration (H1, H2), yet it lacks active bodily interaction (H3) and relies more on visual than verbal expression (H4). Masdar Housing occupies a middle ground: its design encourages social and environmental awareness (H1), prioritizes climate-responsive comfort (H2), and enables some bodily interaction (H3), though it too is weak in linguistic or musical expressiveness (H4).

Artificial Intelligence Dimensions (A1-A3): Babcock Ranch scores high across all AI-related dimensions. It incorporates learning systems and anticipatory design (A1-A3), leveraging real-time data to adapt services to residents' needs. Bosco Verticale, however, centers more on natural aesthetics than on smart systems, showing limited engagement with logical-mathematical and spatial AI components. Masdar Housing integrates adaptive environmental control and smart energy tracking, reflecting moderate to high use of AI, but falls short in spatial intelligence innovation and dynamic self-optimization.

Collective Intelligence Dimensions (C1-C3): Babcock Ranch again leads with strong CI features, offering tools for citizen participation, feedback loops, and shared learning networks (C1-C3). This reflects a well-integrated interpersonal and logical-mathematical dimension, empowering residents as co-managers of their environment. Bosco Verticale ranks lower in this domain, as its focus lies more in passive environmental experience than in participatory governance. Masdar Housing shows moderate scores: while it provides shared spaces and some collective features, its engagement with community-led feedback and co-decision-making is limited.

Reality Typology Dimensions (R1-R3): In terms of spatial and experiential intelligences, Babcock Ranch demonstrates a balanced yet physical approach, leveraging AR moderately (R1), maintaining a strong physical context (R2), and avoiding detached virtual realities (R3). Bosco Verticale's strength lies in its spatial and naturalistic intelligence (R2), expressed through its vertical green design. It scores lower on AR and VR integration. Masdar Housing blends environmental adaptation with existential awareness (R3), employing spatial and contextual strategies to address sustainability, although its immersive or augmented interfaces remain underdeveloped.

Overall, Babcock Ranch is noted for its high integration of social, environmental, and cognitive intelligences. Bosco Verticale focuses more on naturalistic and spatial intelligence but exhibits lower interpersonal and logical engagements. Masdar Housing offers a balance of environmental and interpersonal intelligences but lacks strong integration of logical or artistic expressions.

Conclusion

This study critically examined the distinction between "smart" and truly "intelligent" housing by analyzing three contemporary residential projects, Babcock Ranch, Bosco Verticale, and MasdarCity Housing. Using a multidimensional framework grounded in human (HI), artificial (AI), collective (CI), and spatial-environmental intelligences (Reality Typologies), the research highlighted a significant disparity between technological smartness and holistic intelligence in housing design. It addressed key questions about what sets truly intelligent homes apart from merely smart ones and how selected case studies exemplify or fail to embody these deeper dimensions of intelligence.

While all three case studies integrate digital tools and sustainability strategies to varying degrees, only Babcock Ranch demonstrated a relatively balanced performance across human-centered and collective dimensions. Bosco Verticale prioritized a nature-centric experience but lacked advanced interaction and adaptability features. Masdar Housing emphasized environmental responsiveness but remained limited in personal and expressive engagement. These findings underscore that current smart housing paradigms often prioritize efficiency, control, and passive automation, whereas truly intelligent homes must incorporate learning, mutual adaptation, and deeper user interactions with their users and environments. These observations also reaffirm that HI must precede the use of AI; without this foundation, AI-driven systems may not only fail to support users but can even introduce new risks and vulnerabilities. As several studies (Such as Alzaylaee, 2025, 214; Dunsin, 2025; Akter et al., 2025) caution, neglecting human-centered capacities can turn AI-driven systems into new points of vulnerability rather than protection.

Overall, the findings suggest that current smart housing paradigms still tend to prioritize efficiency, control, and passive automation over learning, mutual adaptation, and embodied human experiences. Bridging this gap requires a shift in housing design from data-driven convenience to intelligence that is cognitive, emotional, social, and existential. True intelligent homes must move beyond system optimization toward environments that sense, learn, evolve, and meaningfully relate to the lives they host.

While this study provides a structured and theory-informed comparison of intelligence in contemporary housing, it is important to acknowledge certain limitations. The selection of three internationally recognized housing projects, although diverse in geography and concept, cannot fully capture the range of smart or intelligent housing practices worldwide. Additionally, the evaluation relied on qualitative scoring informed by conceptual frameworks such as Gardner's Multiple Intelligences, which, despite offering depth, may involve a degree of interpretive subjectivity. Data were derived primarily from secondary sources, limiting access to detailed user experiences or system-level documentation. Furthermore, the rapid evolution of smart technologies means that the findings reflect a specific moment in technological development. At the same time, because this study compares only three cases, its findings should be read as interpretive rather than universally generalizable. The aim here is not to offer a statistical account of intelligent housing around the world, but to use these projects as "theoretical examples" that help us understand how different forms of intelligence take shape in real SH environments. In qualitative comparative work, depth and conceptual clarity matter more than the size of the sample. Still, how far these insights travel depends on how similar other contexts are, and future research that includes more diverse or locally grounded cases would help strengthen both the validity and reliability of the conclusions.

Future AI-integrated systems in SHs should account for the possibility that increasing AI autonomy might inadvertently reduce human cognitive engagement and problem-solving effort (See Farkaš, 2024; Girma, 2025; Lahlou, 2025), highlighting the need for designs that actively support HI alongside AI. Nonetheless, the study offers practical implications for future housing design by suggesting that the next generation of homes must go beyond technical efficiency and move toward holistic, adaptive, and meaning-rich environments that align with real HIs.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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