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Article

Designing for Dignity: Empowering Life Through Synergistic and Integrated Design Solutions for Aging in Place

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Abstract: As global populations age, supporting older adults to age in place—remaining in their homes and communities—emerges as a critical challenge. This study investigates how interior architectural design can integrate human-centered, biophilic, and technology-driven principles with sustainable strategies to enhance the autonomy, safety, and well-being of older adults. Employing a multi-phase methodology, the research synthesizes literature on aging, interior architecture, and technology to establish a comprehensive framework. This framework emphasizes user participation, nature-inspired design, assistive technologies, and adaptable spatial planning. Key findings reveal actionable strategies, such as integrating biophilic elements like daylighting and greenery, employing user-friendly smart technologies, and incorporating universal design features like adjustable countertops and slip-resistant flooring. The proposed framework aligns design interventions with the physical, cognitive, and emotional needs of older adults, promoting environments that foster independence and dignity. Ultimately, the study underscores the importance of interdisciplinary collaboration in creating adaptable, sustainable, and empowering living spaces that enhance quality of life for aging populations.

Keywords: Aging in place; human-centered design; biophilic design; smart technology; dignity; older adults; interior architecture; sustainability

1. Introduction

1.1. Background and Significance

Global demographics are shifting toward a dramatically older population, a trend that poses urgent questions about how to design living environments that enable older adults to remain at home safely and comfortably (United Nations, 2022). This desire to “age in place,” rather than move into institutional settings, is closely linked to improved health outcomes, enhanced autonomy, and stronger community bonds (Means, 2007; Ratnayake, Lukas, Brathwaite, Neave, & Henry, 2022). Research in environmental gerontology highlights that an older adult’s ability to thrive often depends on whether their home environment adapts to physical, sensory, and cognitive changes (Lawton & Nahemow, 1973; Kahana, 1982; Vitiello, G., & Sebillo, M. 2018).

Despite the recognized benefits of aging in place, many conventional housing models fail to address the architectural and interior design needs of older adults (Ahmed et al., 2023; Mnea & Zairul, 2023). Stairs and narrow corridors, poor lighting, absence of grab bars, and limited access to natural elements are among the barriers that impede well-being and autonomy (Engineer, Sternberg, & Najafi, 2018). Moreover, while gerontological research often underscores user-centered and participatory approaches, the practical interior architectural solutions—such as biophilic strategies, ergonomic layouts, and technology integration—are not always systematically implemented (Das,

Arai, & Kim, 2022; Zhuan, S., 2023). An emerging consensus suggests that integrative design practices that combine human-centered engagement, biophilic principles, and assistive technologies can significantly improve older adults' daily experiences (Manca, Cerina, & Fornara, 2019; Shu & Liu, 2022). Such approaches address a spectrum of concerns, from fall prevention and sensory stimulation to emotional comfort, social connectivity, identification and monitoring of cognitive changes, and enhancing functional independence and improving safety and quality of life (Fox et al., 2007; Akl, A. et al., 2016; A. et al., 2017; Piau, A. et al., 2019; Jo, Ma, & Cha, 2021). By strengthening connections between architecture, gerontology, and sustainability, the field can develop holistic frameworks that allow older adults to "age in the right place" with dignity (Ahmed et al., 2023; Nabil et al., 2023).

1.2. Aim and Scope of the Paper

The aim of this paper is to present a comprehensive framework for designing age-friendly interior environments, building upon current discussions in the field. The objective is to integrate key principles to create spaces that promote well-being for older adults. These principles include Human-Centered Design (HCD), which ensures that older adults actively participate in the decision-making process, with interventions that respect their functional, cultural, and emotional needs (Vitiello, G., & Sebillio, M. 2018; D'haeseleer, I. et al., 2021; Ling, T. et al., 2023). The framework also emphasizes Biophilic Integration, introducing nature-inspired features such as daylighting, indoor gardens, and nature views, which support emotional well-being and cognitive health (Park, S. J., & Kim, M. J., 2018; Manca et al., 2019; Van Hoof et al., 2019; Forsyth, A., & Molinsky, J., 2023). In addition, the paper highlights the role of Smart Technologies, leveraging ambient sensors, assistive devices, and intuitive interfaces to enhance safety and independence for older adults (Piau, A. et al., 2019; Lee LN & Kim MJ, 2020; Jo, T. et al., 2021). It also advocates for Sustainable and Ergonomic Interior Architecture, focusing on material selection, space planning, and universal design principles to ensure long-term viability for both users and the environment (Connell, B. et al., 1997; Nabil, M. et al., 2023). While the paper acknowledges broader policy, social, and economic factors, its primary focus is on architectural and interior design interventions that directly influence the well-being of older adults. It connects existing theoretical frameworks, such as person-environment fit and universal design (Ahmed et al., 2023; Nabil, M. et al., 2023), with actionable solutions that can be implemented by architects, interior designers, and gerontological professionals. These solutions include wayfinding cues, adaptive countertops, and low-threshold transitions, all aimed at creating environments that enhance autonomy and quality of life for older adults.

2. Materials and Methods

2.1. Research Design

This study adopts a descriptive-analytical methodology combined with an inductive approach to synthesize existing literature on aging in place, interior architecture, and user-centered design. The investigation is structured around two primary phases:

Literature Review: This phase involved a broad scan of peer-reviewed articles, design case studies, and gerontological reports. The review aimed to inform an understanding of the challenges faced by older adults in living environments, as well as emerging solutions in architecture, biophilic design, and technology.

Conceptual Framework Development: Insights from the literature review were synthesized to formulate an integrative framework. This framework emphasizes human-centered strategies (e.g., participatory design), biophilic principles (e.g., maximizing natural light and introducing greenery), and user-friendly technologies (e.g., ambient assisted living devices and voice-activated systems).

2.2. Data Collection

The data collection process followed a systematic approach with three key steps. First, electronic databases like Scopus, Web of Science, PubMed, and Google Scholar were searched from January 2014 to December 2024 using key terms such as "aging in place," "universal design," "smart home," and "biophilic design." Next, inclusion criteria were set to ensure relevance and quality, focusing on articles addressing design solutions for older adults or aging in place. Studies without a clear methodology or those not published in peer-reviewed journals were excluded. Finally, a rigorous screening and quality assessment (QA) process was conducted using the CASP checklist, resulting in 42 articles that met all inclusion criteria (see **Table A1** in Appendix A for the CASP checklist).

2.3. Data Analysis

Thematic analysis was used to categorize and interpret the data. Articles were coded based on recurring themes, such as challenges (e.g., narrow corridors, poor lighting) and solutions (e.g., universal design, IoT sensors). These were grouped into broader categories like human-centered design, biophilic integration, and technology-enabled aging in place. Guided by Braun and Clarke's (2006) framework, the analysis involved familiarization with the data, initial coding, theme development, and refinement. Emerging themes were cross-compared to identify intersections between architectural interventions, user engagement, and sustainability, with discrepancies resolved through team discussions (see **Table A2** and **Table A3** in Appendix B for challenges and solutions coding)..

2.4. Ethical Considerations

While this research relies on literature-based data, ethical reflection was ensured. Fair representation was prioritized by accurately synthesizing diverse study contexts and perspectives. Cultural sensitivity was emphasized, acknowledging that design must adapt to local norms and individual preferences. Integrity was maintained through proper citation and acknowledgment of study limitations. The combination of architecture, gerontology, and technology literature with thematic coding and conceptual modeling provides a robust foundation for proposing integrative design solutions that address the physical, cognitive, and emotional needs of older adults, promoting a dignified aging-in-place experience.

3. Results

3.1. Literature Review

3.1.1. Aging in Place: Concepts and Gerontological Foundations

The concept of aging in place—where older adults continue living in their homes and communities as they age—is widely recognized for its benefits in autonomy, mental and cognitive health, and economic viability (Mayo, C. et al., 2021; Means, 2007; Ratnayake, et al., 2022). Such arrangements foster the continuity of social ties, contribute to a sense of identity, and reduce the emotional distress often associated with institutional care (Mnea & Zairul, 2023). In environmental gerontology, this person–environment fit is highlighted as a key determinant of older adults' well-being: supportive physical settings should be congruent with an individual's changing functional capacity (Lawton & Nahemow, 1973; Kahana, 1982). Global forecasts reveal a rapidly expanding demographic aged 65 and above, intensifying the demand for innovative housing approaches (Das, Arai, & Kim, 2022; United Nations, 2022). This shift calls for interior environments that adapt to sensory, cognitive, and mobility changes, while also accommodating diverse cultural contexts and personal preferences (Ahmed et al., 2023). Traditional homes—often not designed with older adults in mind—can undermine independence, leading to safety hazards, social isolation, and increased healthcare costs (Miller, Vine, & Amin, 2016). Consequently, aging in place is increasingly seen as not

just a personal preference but a public health priority (WHO, 2015; Engineer, Sternberg, & Najafi, 2018). Foundational gerontology theories—such as the Ecological Model of Aging (Lawton & Nahemow, 1973) and Congruence Model (Kahana, 1982)—emphasize the dynamic interplay between personal competence and environmental press. When physical or cognitive challenges outpace environmental support, older adults may experience reduced autonomy or a higher risk of injuries (D'haeseleer, Gielis, & Abeele, 2021). By contrast, environments that match functional and psychosocial needs are linked to positive health outcomes, improved emotional well-being, and extended independence (Ahmed et al., 2023; Nabil, El Shair, Taher, & Zyada, 2023).

3.1.2. Architectural and Interior Design Challenges

Despite growing awareness of the need for age-friendly dwellings, numerous interior architectural barriers persist in typical housing stock (Ahmed et al., 2023; Mnea & Zairul, 2023). These can be grouped under five main categories, as illustrated in Figure 1, which highlights the environmental challenges older adults face in navigating their living spaces:

Physical Barriers and Lack of Ergonomic Adaptability: Interiors frequently include narrow corridors, steep steps, or limited turning radius, rendering mobility aids (walkers, wheelchairs) difficult to maneuver (Engineer et al., 2018; Shu & Liu, 2022). High countertops, fixed cabinetry, and standard-height fixtures also limit older adults' ability to carry out basic tasks (Wang, Lin, & Huang, 2022). Bathrooms without accessible features—such as grab bars or anti-slip flooring—remain a leading cause of falls (Romli et al., 2016; Moreland B. et al., 2020).

Poor Lighting and Reduced Visual Accessibility: Natural and artificial lighting is often insufficient or poorly calibrated for age-related visual changes (Fox, Stathi, McKenna, & Davis, 2007; Bennetts, Martins, & van Hoof, 2020). Older adults may struggle with glare or inadequate contrast in floor edges, leading to disorientation or falls (Engineer et al., 2018; Moreland B. et al., 2020). Research suggests that circadian-friendly lighting—dynamic systems that align with natural rhythms—can improve mood, sleep patterns, and mental clarity (Sander, Markvart, Kessel, Argyraki, & Johnsen, 2015).

Limited Biophilic Integration: While biophilic design can reduce stress and support cognitive functioning through greater exposure to nature and daylight, many homes lack strong indoor-outdoor connections (Manca, Cerina, & Fornara, 2019; Van Hoof, Bennetts, Hansen, Kazak, & Soebarto, 2019). Narrow windows, minimal greenery, and the absence of transitional spaces like balconies or patios can deprive seniors of opportunities for restorative natural experiences (Peng & Maing, 2021).

Ineffective Wayfinding and Spatial Organization: Unclear room hierarchies, repetitive corridors, and complex layouts hamper older adults—particularly those with cognitive impairments (Ahmed et al., 2023). A lack of visual or tactile cues may compound confusion and prompt reliance on caregivers for navigation (Das et al., 2022). Failing to design with cognitive accessibility in mind can undermine autonomy, raise stress, and increase the risk of accidents (Demirkan & Olguntuerk, 2013).

Technology and Usability Gaps: Ambient assisted living devices, such as fall-detection sensors or smart home controllers, are frequently installed without accounting for older adults' preferences or limitations (Lee, Gu, & Kwon, 2020). Complicated user interfaces, poorly placed sensors, or opaque privacy policies can deter adoption (Borelli et al., 2019; Fournier, H. et al., 2021). Integrating user-friendly interfaces (touchscreens with larger fonts, voice-activated assistants) remains an underexplored dimension of interior architecture (Engineer et al., 2018).

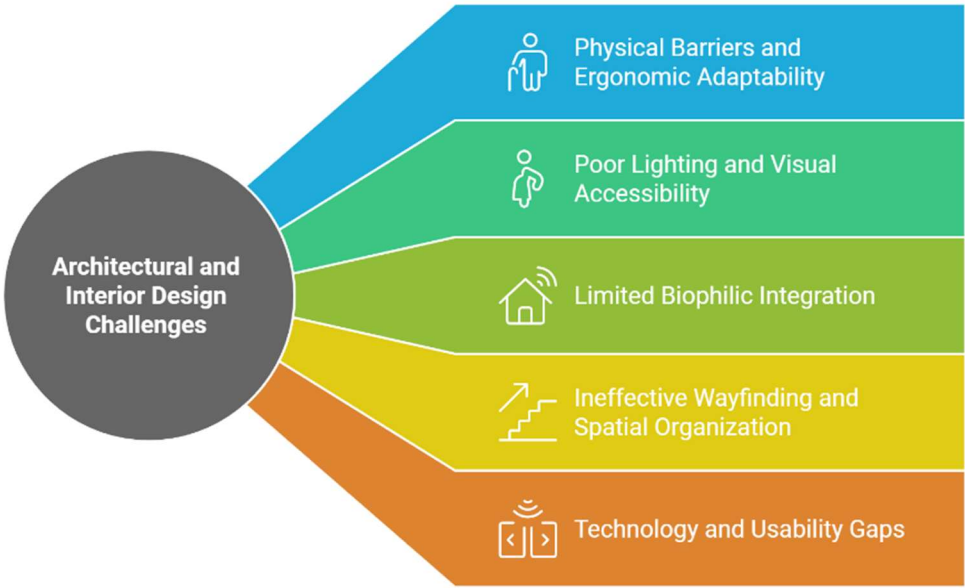


Figure 1. Navigating Environment Challenges for Older Adults.

3.1.3. Existing Approaches

In response to these challenges, several design philosophies and practical interventions have emerged.

Universal (or Inclusive) Design: Universal design, sometimes termed “design for all,” seeks to accommodate a wide range of users by incorporating flexibility, simplicity, and intuitive use from the outset (Connell, B. et al., 1997; Demirkan & Olguntuerk, 2013; Sandholdt, C. et al., 2020). Evidence indicates that universal design features—e.g., lever-type handles, low-threshold doors, and adjustable work surfaces—enhance safety, comfort, and independence for older adults (Ling et al., 2023). Yet researchers highlight the need for ongoing refinement: a strictly code-based or prescriptive approach may still ignore nuanced cultural and personal preferences (Tsuchiya-Ito & Iwarsson, 2019; Zhuan, S., 2023).

Biophilic and Sustainable Interior Strategies: Biophilic integration brings elements of nature—daylight, greenery, natural materials—into indoor living spaces (Manca et al., 2019; Fox et al., 2007). Studies show that exposure to nature can lower stress, support mental health, and encourage physical activity—especially valuable for older adults (Van Hoof et al., 2019). Sustainable design approaches, such as maximizing daylighting or reducing VOC-emitting materials, further improve indoor air quality and occupant health (Park & Kim, 2018; Ahmed et al., 2023). However, ensuring these interventions are user-friendly and customizable is critical for long-term acceptance (Mnea & Zairul, 2023).

3.1.4. Gaps and the Need for an Integrated Framework

Despite the progress in universal design, biophilic principles, and smart-home innovations, fragmented application persists (Fournier, H. et al., 2021; Ahmed et al., 2023). Architectural and interior design solutions often address isolated problems—such as slip-proof flooring—without addressing more comprehensive factors like circadian lighting, intuitive wayfinding, or nature-inspired transitions (Manca et al., 2019; Engineer et al., 2018). Additionally, cultural contexts, socioeconomic conditions, and policy limitations complicate broader adoption (Das et al., 2022; Mnea & Zairul, 2023).

Researchers advocate a multidisciplinary approach that combines architectural insights with gerontology, environmental psychology, and technology design (D'haeseleer et al., 2021; Shu & Liu, 2022). Such holistic interventions can better match older adults' lived realities, ensuring dwellings remain safe, engaging, and adaptable over time (Lawton & Nahemow, 1973; Ahmed et al., 2023). This calls for an integrative framework—one that unites user participation, nature-inspired design, accessible technologies, and interior architectural planning into a single, user-centered model for aging in place.

3.2. Findings and Recommendations

3.2.1. Spatial Design Challenges

One of the common architectural challenges for older adults is the insufficient width of corridors, doorways, and hallways, which can impede mobility devices such as walkers or wheelchairs (Engineer, Sternberg, & Najafi, 2018; Ahmed et al., 2023). Older homes often feature door widths narrower than 32 inches, or hallways that fail to accommodate two-way traffic, creating bottlenecks and increasing the risk of falls (Das, Arai, & Kim, 2022). For example, a study of long-term care facilities in Sweden found that corridors narrower than 1.4 meters forced staff to maneuver residents sideways, adding stress and potential hazards (Granbom, Iwarsson, & Kylberg, 2016). Similarly, private homes designed decades ago often do not consider the turning radii for wheelchairs in tight hallways (Mnea & Zairul, 2023).

Another significant issue is wayfinding and spatial confusion, particularly for older adults with mild cognitive impairments. Unclear floor plans, repetitive layouts, and a lack of signage exacerbate navigational difficulties (Das et al., 2022). The absence of visual landmarks or distinct color zones further contributes to confusion, diminishing autonomy (Ahmed et al., 2023; Nabil, El Shair, Taher, & Zyada, 2023). A Taiwanese study on typical residential settings revealed that older adults with early dementia heavily relied on familiar objects for orientation. When these objects were absent or moved, participants reported frequent disorientation within their own homes (Demirkan & Olguntuerk, 2013).

Inadequate bathroom and kitchen design is another pressing concern. High fixtures, lack of grab bars, slippery tiles, and minimal space for maneuvering in bathrooms remain leading causes of falls and hospitalizations among older adults (Romli et al., 2016; Moreland B. et al., 2020). Kitchens with standard-height countertops, limited reach ranges, and poorly placed appliances complicate cooking tasks (Wang, Lin, & Huang, 2022). For instance, a comparative study of senior living units in Malaysia revealed that only 25% of units had non-slip flooring, and fewer than 10% featured handrails in bathrooms (Ratnayake, Lukas, Brathwaite, Neave, & Henry, 2022). Participants in the study reported a fear of falling in wet areas and avoided showering independently as a result.

The issue of insufficient daylighting and visual contrast is particularly important for older adults, who often struggle with age-related vision impairments, such as reduced accommodation, sensitivity to glare, and difficulty discerning contrasts (Fox, Stathi, McKenna, & Davis, 2007). When windows are small, covered by heavy drapes, or poorly oriented, the living space can feel gloomy, which can trigger depressive symptoms (Manca, Cerina, & Fornara, 2019). A pilot retrofit in a Canadian nursing home, which replaced dark drapery and added skylights to communal areas, demonstrated positive results. Residents reported improved mood and alertness, and there were anecdotal observations of increased social engagement (Engineer et al., 2018).

Finally, the integration of technology, particularly smart home technologies, presents several barriers. While these technologies can enhance safety and comfort, many interfaces are not age-friendly. Issues such as voice-activated systems with small or hidden "mute" buttons, or sensor placements that do not account for older adults' typical routines, complicate usability (Lee, Gu, & Kwon, 2020; Fournier, H. et al., 2021). Furthermore, cost and limited tech literacy continue to present significant obstacles (Borelli et al., 2019). For example, one senior housing complex in Hong Kong installed motion sensors in bedrooms and bathrooms but experienced frequent false alarms due to

incorrect sensor positioning or the older adults not using those areas at the expected times (Peng & Maing, 2021; Ahmed et al., 2023).

3.2.2. Proposed Solutions

Wayfinding: Effective wayfinding strategies are crucial for older adults, particularly in complex environments. Clear signage and visual cues can significantly enhance navigation. Large-font signs with pictograms and contrasting colors, placed at strategic decision points, can improve clarity and reduce confusion (Ahmed et al., 2023). Additionally, color-coded pathways, where different hues are assigned to corridors leading to specific areas, can further aid in orientation (Das et al., 2022). Tactile flooring, such as textured strips or raised patterns, can help older adults identify room thresholds through touch, improving spatial awareness (Demirkan & Olguntuerk, 2013). Finally, intuitive layouts with direct sightlines to communal areas, reduced blind corners, and the clustering of related functions can further simplify navigation (Engineer et al., 2018).

Lighting & Ergonomics: Lighting and ergonomics play an essential role in the well-being of older adults. Dynamic circadian lighting systems that shift color temperature throughout the day can promote healthier sleep-wake cycles and improve overall health (Sander et al., 2015). To enhance safety, slip-resistant flooring with raised textures or coatings should be prioritized in high-risk zones such as bathrooms, kitchens, and entryways (Romli et al., 2016). Adjustable countertops and cabinets, which allow older adults to customize heights according to their changing mobility and posture, are another vital ergonomic solution (Wang et al., 2022). Additionally, replacing doorknobs with lever handles, expanding hallway widths to at least 1.5 meters, and ensuring low-threshold or zero-step entries can further improve accessibility (Ahmed et al., 2023).

Biophilic Integration & Indoor-Outdoor Transitions: Integrating biophilic design and facilitating smooth transitions between indoor and outdoor spaces can significantly enhance the environment for older adults. Large windows and skylights can increase natural light penetration and reduce dark spots, mitigating symptoms of depression (Manca et al., 2019). Easy-access gardens, providing direct, level access to courtyards or balconies with raised planters, encourage moderate physical activity and connection to nature (Peng & Maing, 2021). The incorporation of green walls and natural materials, such as indoor vegetation, wooden surfaces, and water features, can further boost cognitive engagement and provide stress relief (Fox et al., 2007).

User-Friendly Technology: User-friendly technology can significantly enhance the independence and safety of older adults. Voice-activated controls, which reduce the need for manual dexterity, can be integrated into systems for lighting, HVAC, or emergency calls, making these systems more accessible (Jo, Ma, & Cha, 2021). Fall-detection sensors, strategically placed in high-risk areas like bathrooms and bed areas, can help prevent accidents, provided they have low rates of false alarms (Borelli et al., 2019). Accessible interfaces with large buttons, tactile feedback, and contrast-rich screens are essential for accommodating visual or motor impairments (Shu & Liu, 2022). Interfaces designed to display short, simple, and low-complexity information or sentences can enhance accessibility for older adults with cognitive impairments. Interfaces should prioritize clear, easily readable text, intuitive navigation, and minimal distractions to support ease of use and comprehension for older adults with cognitive impairment. (Chen, L., & Liu, Y., 2017; Chen, L., & Liu, Y., 2022; Castilla, D. et al., 2020). Finally, the strategic placement of devices, such as sensors near entry points or seating areas, ensures maximum reliability and ease of use (Lee et al., 2020).

3.2.3. Evidence-Based Benefits

One example of successful design implementation comes from a senior housing pilot project in the UK, where circadian lighting was introduced in the hallways. Over a period of three months, staff observed a 30% reduction in reported nighttime wandering, along with a modest but significant improvement in residents' subjective sleep quality (Sander et al., 2015). Another case from Mauritius involved older adults participating in retrofitting their kitchens with adjustable countertops and pull-down shelving. Post-evaluation interviews revealed higher satisfaction levels and an improved

ability to cook independently, emphasizing the effectiveness of adaptive design in enhancing daily living (Ramsamy-Iranah, Maguire, Peace, & Pooneeth, 2021).

While the initial capital investment for retrofitting homes with wider doorframes, sensor systems, and adaptive lighting may seem high, evidence indicates substantial long-term healthcare savings. These savings stem from reduced fall-related hospitalizations and improved mental health outcomes (Ahmed et al., 2023; Engineer et al., 2018). Retrofitting an older adult’s home with features such as slip-resistant floors and smart lighting may cost less than a few months of institutional care or repeated hospital visits (Miller, Vine, & Amin, 2016). Furthermore, by prolonging independent living, families benefit both financially and emotionally, as older adults can remain in familiar environments with reduced reliance on caregivers (Means, 2007).

Several public-private partnerships, including collaborations between local housing authorities and technology providers, have funded pilot programs demonstrating that even partial upgrades—such as the installation of lever handles, motion-sensor lights, or tub-to-shower conversions—can significantly lower injury rates (Borelli et al., 2019; Peng & Maing, 2021). Therefore, from both an economic and well-being perspective, investing in aging-in-place design can yield returns that surpass the initial installation costs (Das et al., 2022; Shu & Liu, 2022).

4. Discussion

4.1. Conceptual Framework

This section proposes an integrative model that brings together human-centered design (HCD), biophilic strategies, and assistive technologies within an overarching architectural layout approach for aging in place. The framework treats older adults as active co-creators, with iterative feedback loops to adapt and refine design features as users’ needs. As illustrated in **Figure 2**, a key principle is continuous improvement—design features (whether a countertop height, sensor placement, or lighting system) undergo user testing and are refined over time (Jo, Ma, & Cha, 2021; Ling, T.et al., 2023). This cyclical adaptation aligns with the ecological model of aging, ensuring that the environment remains responsive to physical or cognitive changes (Lawton & Nahemow, 1973; D’haeseleer, Gielis, & Abeele, 2021).

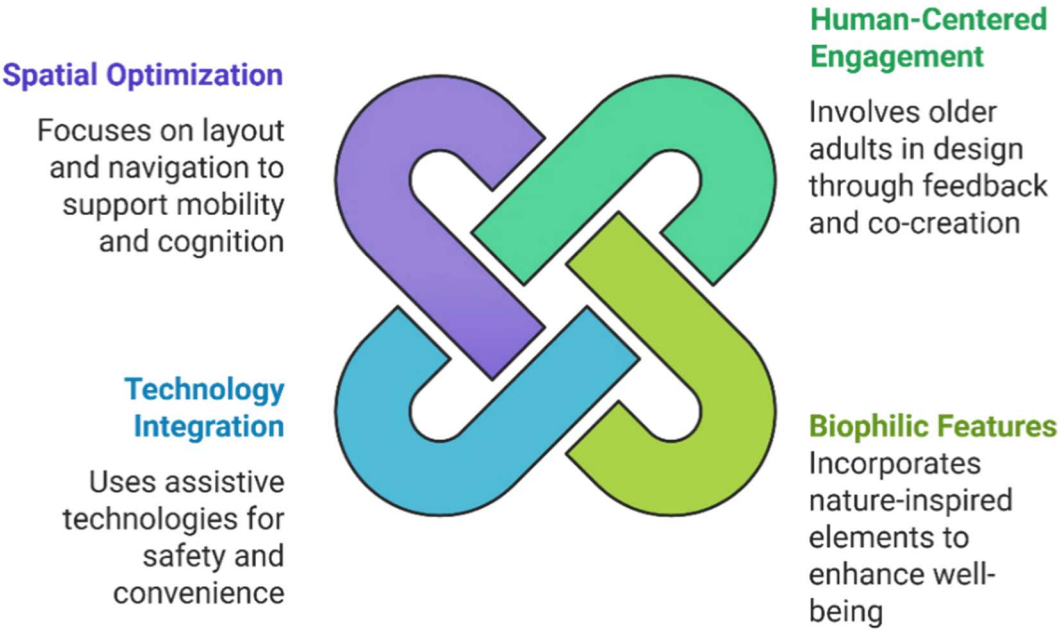


Figure 2. Integrative Model for Aging in Place.

Framework Components:

The proposed integrative model weaves together several essential components to optimize design for aging populations:

Human-Centered Engagement:

Participation and Co-Creation: As depicted in **Figure 3**, older adults and caregivers can be actively involved in the design process through focus groups and mock-ups. These activities simulate daily tasks—e.g., traversing corridors, using kitchen counters, or reading signage—to gather firsthand feedback on spatial adequacy (Das, Arai, & Kim, 2022; Ahmed et al., 2023). Based on this feedback, iterative adjustments can be made to elements such as hallway widths, furniture placement, or color schemes, ensuring alignment with users’ physical abilities and preferences (D’haeseleer, Gielis, & Abeele, 2021).

Cultural and Individual Sensitivity: Recognizing the diverse needs of older adults, designers can consider varying aesthetics, such as color preferences, material choices, or privacy needs, which may influence corridor brightness or bedroom layout (Demirkan & Olguntuerk, 2013; Ling et al., 2023). Additionally, incorporating personal artifacts, such as built-in shelves or display areas for mementos, can reinforce identity and emotional comfort (Mnea & Zairul, 2023).

By systematically integrating older adults’ perspectives, as illustrated in **Figure 3**, designers can move beyond merely retrofitting standard designs to create truly inclusive environments (Sandholdt et al., 2020; Zhuan, 2023).



Figure 3. Human-Centered Design for Aging in Place.

Biophilic and Sustainable Features:

Nature-Inspired Strategies: As illustrated in **Figure 4**, biophilic design can play a critical role in creating environments that promote well-being and reduce stress for older adults. Key strategies include daylighting, achieved through oversized windows, skylights, or light wells in living rooms and corridors, ensuring users can easily navigate and remain oriented to the time of day (Fox et al., 2007). Additionally, unused nooks can be transformed into indoor green zones, offering micro-restorative spaces that encourage gentle activity and stress relief (Manca et al., 2019). Incorporating natural ventilation systems, such as cross-ventilation, indoor planters, or green walls, further enhances the environment by introducing fresh air and visual stimuli (Van Hoof et al., 2019).

Sustainability Elements: o align with eco-friendly principles, designers can incorporate low-VOC paints, recycled flooring, and ethically sourced timber to improve indoor air quality and minimize environmental impact (Park & Kim, 2018). Energy-efficient systems, such as LED-based circadian lighting with sensor-driven controls, reduce energy costs while enhancing occupant well-being (Sander et al., 2015; Miller, Vine, & Amin, 2016).

By integrating these elements, biophilic design not only promotes stress reduction and emotional well-being but also supports physical activity, such as gardening in courtyards, thereby reinforcing older adults' overall health and quality of life (Manea & Zairul, 2023).



Figure 4. Biophilic Design Benefits for Aging in Place.

Technology Integration

Assistive and Monitoring Devices: As shown in **Figure 5**, assistive technologies can enhance safety and functionality for older adults. Non-intrusive sensors, such as fall-detection devices, can be strategically placed at corridor transitions or changes in floor levels, calibrated to older adults' traffic patterns, especially near bathrooms and bedrooms (Engineer et al., 2018; Borelli et al., 2019). Smart lighting controls, including voice-activated or motion-based triggers, ensure intuitive and safe illumination in corridors (Jo, Ma, & Cha, 2021). Emergency call systems, such as accessible panic buttons or voice-activated help calls, can be placed in living rooms and kitchens for immediate assistance (Engineer et al., 2018).

User-Friendly Interfaces: Control panels with larger screens and clear icons, situated at accessible heights near corridor intersections or seating areas, enhance usability (Shu & Liu, 2022). Voice-activated controls for lights, heating, and appliances reduce reliance on manual dexterity (Jo et al., 2021). Predictive analytics powered by machine learning algorithms can analyze daily routines to provide early warnings of health risks, cognitive changes, or functional decline (Shu & Liu, 2022).

Privacy and Training: Addressing privacy concerns is essential, with clear consent options and user training mitigating potential discomfort with continuous monitoring (Lee, Gu, & Kwon, 2020). Onboarding sessions tailored to older adults' learning pace ensure they can comfortably operate devices without technology becoming a barrier (Peng & Maing, 2021).

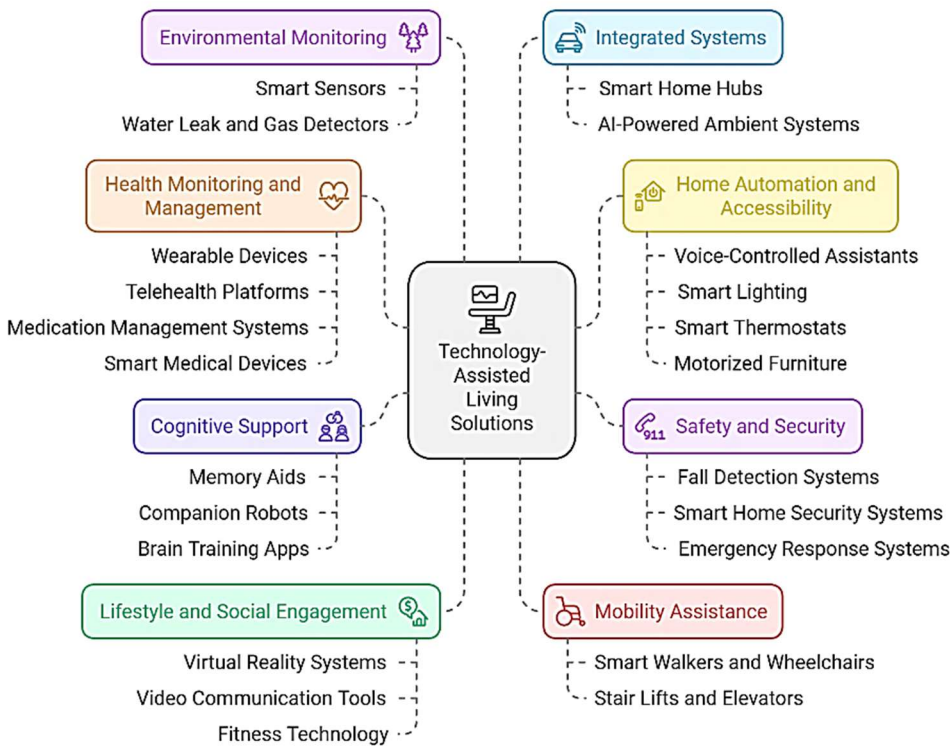


Figure 5. Technology-Assisted Living Solutions.

Spatial Factors

Layout Efficiency and Wayfinding: As depicted in **Figure 6**, efficient layouts are crucial for supporting older adults’ mobility and safety. Optimized corridor widths of 1.2 to 1.5 meters minimize collision risks with mobility aids and allow for two-way passage (Ahmed et al., 2023; Das et al., 2022). Strategic room adjacencies, such as placing high-use rooms like bathrooms near bedrooms, reduce fatigue and unnecessary long-distance movement (Demirkan & Olguntuerk, 2013).

Color, Texture, and Finishing: Distinct floor-wall color contrasts and trim details can visually guide older adults, marking level changes or indicating doorways (Fox et al., 2007). Slip-resistant surfaces, such as textured tiles or anti-slip coatings in kitchens, entry areas, and bathrooms, enhance safety and reduce fall risks (Romli et al., 2016; Moreland et al., 2020).

Furniture Layout: Arranging seating and tables to create clear circulation routes supports mobility, while lightweight or modular furniture allows flexible reconfiguration to adapt to changing health needs (Mnea & Zairul, 2023).

Adaptive and Flexible Interiors: Movable partitions enable older adults to adjust space sizes based on their mobility or caregiving demands (Engineer et al., 2018). Low-threshold transitions eliminate floor-level disparities between rooms, ensuring smooth movement for walkers or wheelchairs (Lee et al., 2020).

By implementing these spatial design strategies, as illustrated in **Figure 6**, designers can enhance older adults’ ability to navigate, perform daily tasks, and remain cognitively engaged in their surroundings (Kahana, 1982; Lawton & Nahemow, 1973).

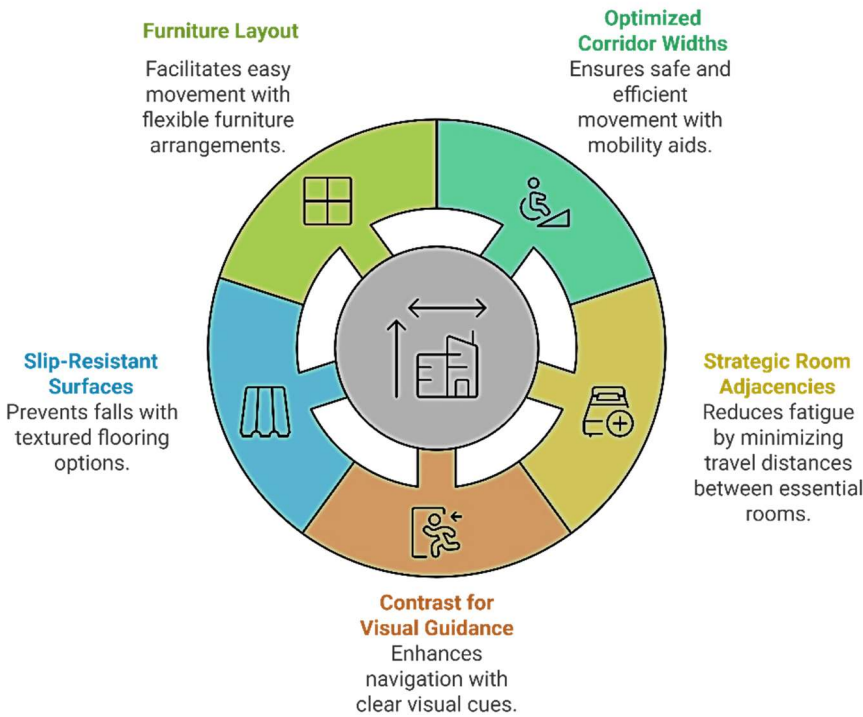


Figure 6. Spatial Design Strategies for Older Adults.

4.2. Implementation Pathway

A four-stage process, as illustrated in **Figure 7**, enables the practical application of the integrated design framework for aging in place:

Pilot Testing and Spatial Mock-Ups: Full-scale prototypes of critical spaces, such as corridors, kitchens, and bathrooms, are constructed to facilitate observation and co-creation with older adults and caregivers (Mnea & Zairul, 2023).

User Feedback and Refinement: Adjustments to corridor widths, color schemes, lighting intensity, or device placement are made based on occupant preferences and safety metrics, ensuring spaces align with user needs (D’haeseleer et al., 2021).

Scaling and Policy Engagement: Collaboration with local authorities to adopt building codes that mandate universal hallway widths, step-free entries, and slip-resistant finishes is critical. Incentives such as grants or subsidies can encourage homeowners and developers to implement these changes (Means, 2007; Park & Kim, 2018; Miller, Vine, & Amin, 2016).

Long-Term Evaluation and Support: Post-occupancy evaluations conducted over multiple years track fall rates, user satisfaction, and cost-effectiveness. Maintenance plans, technology updates, and ongoing user training ensure that solutions remain aligned with evolving abilities (Shu & Liu, 2022; Peng & Maing, 2021).

By embedding spatial factors into this comprehensive framework—alongside human-centered engagement, biophilia, and technology—this model ensures older adults benefit from environments that are not only safe and intuitive but also adaptive, restorative, and empowering (Engineer et al., 2018; Ahmed et al., 2023).

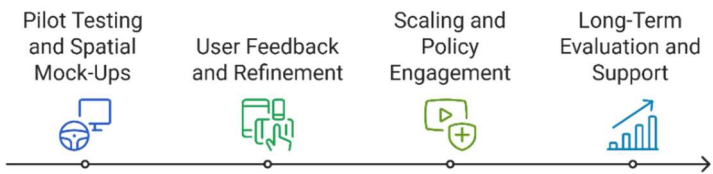


Figure 7. Implementation Pathway for Integrated Design.

4.3. Barriers and Limitations

Cost Constraints and Funding Gaps: The upfront costs for aging-in-place modifications, including structural changes and IoT installations, can be substantial, particularly for low- to middle-income seniors (Engineer et al., 2018; Stavrotheodoros et al., 2018; Sokullu et al., 2020). Potential solutions include public-private partnerships, municipal grants, and incorporating aging-in-place features into insurance or mortgage programs, such as discounted mortgage rates for homes with universal design elements or partial coverage under health insurance for fall-prevention measures (Peng & Maing, 2021; Connell et al., 1997; Ahmed et al., 2023).

Cultural Resistance or Tech Illiteracy: Some older adults may resist perceived "overmodernization" or lack the digital literacy to operate technologies such as voice-activated controls or sensor-based monitors (Jo, Ma, & Cha, 2021). Solutions include gradual technology adoption, starting with small, intuitive devices like sensor lights, and localized education efforts, such as workshops or home visits, to ensure older adults and caregivers are confident in using the devices (Borelli et al., 2019; Lee et al., 2020).

Workforce and Professional Gaps: There is a shortage of trained professionals capable of designing, installing, and maintaining age-friendly features or IoT systems (Stavrotheodoros et al., 2018; Ahmed et al., 2023). Solutions include incorporating "design for aging" modules into architecture, engineering, and technology curricula, and fostering cross-sector partnerships between software designers, interior architects, and occupational therapists to bridge the gap between technology and accessibility (Demirkan & Olguntuerk, 2013; Engineer et al., 2018).

4.4. Future Research

While interventions like adjustable countertops or sensor-assisted fall detection show promising short-term results, there is a lack of longitudinal research on user adaptation and sustained well-being (Das et al., 2022; Nabil et al., 2023). Studies exploring the long-term impact of these interventions and their cultural acceptability are scarce (Mnea & Zairul, 2023).

AI-driven ambient systems offer exciting potential for future research. Predictive analytics and machine learning can detect subtle shifts in gait, sleep patterns, or social engagement, enabling proactive interventions (Shu & Liu, 2022). Future studies could compare AI-enabled systems with simpler automated solutions, assessing adherence, privacy concerns, and clinical outcomes (Borelli et al., 2019).

Comparative pilot projects testing various interior design prototypes—ranging from open-plan to multi-zoned layouts—could provide insights into balancing privacy, social interaction, and mobility (Engineer et al., 2018). Researchers could compare variables like lighting schedules, materials, and sensor placements, measuring user satisfaction, cost-effectiveness, and health outcomes (Peng & Maing, 2021).

Continued innovation and rigorous evaluation are necessary to refine integrative design solutions that promote dignity, autonomy, and quality of life for older adults aging in place.

5. Conclusions

Aging-in-place research highlights the significant impact of interior architecture on older adults' physical comfort, cognitive support, and emotional well-being. Simple adjustments like widening corridors or using circadian lighting can reduce fall risks and disorientation, while smart sensors and biophilic features enhance safety and psychological health. Human-centered design, nature-inspired elements, and assistive technologies create a synergistic toolkit for maintaining dignity, safety, and independence at home.

Widespread adoption of these solutions benefits individuals, families, and communities by lowering accident rates, improving well-being, and reducing healthcare demands. Collaboration among architects, policymakers, clinicians, caregivers, and technology developers is crucial for implementing cost-effective, culturally sensitive, and scalable interventions. Aligning building codes,

offering retrofit incentives, and incorporating universal design in curricula can create a sustainable path for inclusive aging in place.

Enabling older adults to stay in their homes with autonomy and fulfillment is both a moral imperative and a social investment in intergenerational solidarity and resource efficiency (WHO, 2015). As research evolves, advanced sensor systems, AI-driven intelligence, and biophilic strategies will further enhance seniors' daily lives. Ultimately, dignified, holistic design fosters communities where aging is embraced as a stage of life enriched by freedom, safety, and connection.

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Appendix A

CASP Checklist Table

- Legend for Each Column:
- Clear Research Aim: Did the source articulate a focused or clearly stated research question/aim/objective?
- Appropriate Methodology: Did the source use a suitable methodological approach for its aim (qualitative, quantitative, systematic review, etc.)?
- Valid Results: Does it provide reliable data or logically argued findings/conclusions?
- Credible Authors/Source: Are the authors reputable or the source peer-reviewed/academically recognized?
- Relevant to Topic: Does it focus on aging in place, architectural design for older adults, or related interventions?
- Overall CASP Rating: High/Moderate/Low. (Rough measure of overall trustworthiness for your research synthesis.)
- Notes/Comments: Brief remarks on strengths or limitations.

Table A1. CASP Checklist Table.

	Clear Ref Research Aim?	Appropriate Methodology ?	Valid Results?	Credible Authors/Sourc e?	Relevant to Topic?	Overall CASP Rating	Notes/Comments
1	Yes	Yes	Yes	Yes	Yes	High	Presents a framework bridging architecture & gerontology. Well-aligned with aging-in-place.
2	Yes	Yes	Yes	Yes (IEEE journal)	Yes	High	Robust method for detecting MCI in older adults at home. Strong technical approach.

3	Yes	Yes	Yes	Yes (Journal)	Yes	High	Clustering home activities for MCI detection. Novel approach, well-grounded results. Explores thermal comfort of older adults in housing. Good sample and peer-reviewed.
4	Yes	Yes	Yes	Yes (IJERPH)	Yes	High	
6	Yes	Yes	Yes	Yes (Sensors journal)	Yes	High	IoT solution (HABITAT) for independent older adults. Peer-reviewed. Usability study for ICTs in mild cognitive impairment.
7	Yes	Yes	Yes	Yes (IJERPH)	Yes	High	Rigorous approach. Interface design for cognitively impaired older adults. Relevant.
8	Yes	Yes	Yes	Yes (IJERPH)	Yes	High	Addresses affordances, dementia-friendly design. Peer-reviewed conference proceedings.
9	Yes	Yes	Yes	Yes (Procedia CIRP)	Yes	High	Foundational universal design principles from a credible source.
10	Yes	Yes	Yes	Yes (Center for Universal Design)	Yes	High	
12	Yes	Yes	Yes	Yes (Architectural Science Review)	Yes	High	Presents a design-for-all approach to guide independent living. Well-documented. Discusses user-centered design for self-management.
13	Yes	Yes	Partially	Yes	Yes	Moderate	Some specifics lacking, but relevant.
14	Yes	Yes	Yes	Yes (Gerontology journal)	Yes	High	Review on interior design strategies to mitigate age-related deficits. Climate change and aging. Peer-reviewed. Expands context of older adults' well-being.
15	Yes	Yes	Yes	Yes (Housing Policy Debate)	Yes	High	

16	Yes	Yes	Yes	Yes (Springer LNCS)	Yes	High	Smart tech and IoT for aging in place. Well-grounded. Explores physical activity/well-being for older adults.
17	Yes	Yes	Yes	Yes (Eur J Appl Physiol)	Yes	High	Somewhat indirect but relevant to supportive environments. Observational study about
18	Yes	Partially	Yes	Yes (AJOT)	Yes	Moderate	housing accessibility upon relocation. Data is valid. IoT-based
19	Yes	Yes	Yes	Yes (Sensors journal)	Yes	High	integrated smart-home system for older adults. Useful and credible. Classic theoretical
20	Yes	Theoretical Model	Yes (conceptually)	Yes (Gerontology classic)	Yes	High	model (person-environment fit). Historical but fundamental. Foundational
21	Yes	Theoretical Model	Yes (conceptually)	Yes (APA)	Yes	High	ecology/aging model. Very relevant. Critical review of
22	Yes	Yes	Yes	Yes (Front. Psychol.)	Yes	High	smart residential environments. In-depth. Human-centric
23	Yes	Yes	Yes	Yes (IJERPH)	Yes	High	approach to design criteria in Taiwan for aging in place. Compares high- vs.
24	Yes	Yes	Yes	Yes (Social Psychological Bulletin)	Yes	High	low-humanized facilities, relevant to design interventions. Focus on older
25	Yes	Partially (Self-report)	Yes	Yes (Can Geriatr J)	Yes	Moderate	adults with self-reported cognitive decline. Data is self-reported, but valid. Ageing in place
26	Yes	Yes	Yes	Yes (Social Policy & Admin)	Yes	High	policy and social perspective. Widely cited. Examines energy
27	Yes	Yes	Yes	Yes (Energy Policy)	Yes	High	efficiency in older citizens' housing. Relevant to design & environment.

28	Yes	Yes	Yes	Yes (Buildings)	Yes	High	Thematic review on interior design for elderly independence. Excellent fit for your study.
29	Yes	Partially (Surveillance Data)	Yes	Yes (CDC MMWR)	Yes	Moderate	Large-scale epidemiological data on nonfatal falls. Indirect, but relevant to design for fall prevention. Focus on elderly-friendly home environments in Egypt. Matches your design scope.
30	Yes	Yes	Yes	Yes (Journal Eng. Sciences)	Yes	High	Green remodeling for the elderly. Peer-reviewed.
31	Yes	Yes	Yes	Yes (Energies)	Yes	High	Age-friendly neighborhood design in HK. Good empirical work.
32	Yes	Yes	Yes	Yes (Cities)	Yes	High	Systematic review of digital biomarker tech for MCI. Highly relevant to home-based monitoring.
33	Yes	Yes	Yes	Yes (JMIR)	Yes	High	Brief overview of Aging in Place in a specific region. Good policy insight.
34	Yes	Partially	Yes	Yes (Delaware J. Public Health)	Yes	Moderate	HOME FAST tool feasibility for older Malaysians. Robust pilot study.
35	Yes	Yes	Yes	Yes (BMJ Open)	Yes	High	Explores circadian lighting effects on older adults. Strong methodological detail.
36	Yes	Yes	Yes	Yes (Chronobiol Int.)	Yes	High	Addresses human-centered design in health innovation. Good conceptual coverage.
37	Yes	Yes	Partially	Yes (IJERPH)	Yes	Moderate	AI computing for universal design in healthy housing. Technically solid.
38	Yes	Yes	Yes	Yes (Comp. Intell. Neurosci.)	Yes	High	Explores IoT-based solutions for the elderly. Peer-reviewed, rigorous.
39	Yes	Yes	Yes	Yes (Internet of Things)	Yes	High	

40	Yes	Yes	Yes	Yes (IFIP AI & Innovations)	Yes	High	Smart-home IoT for older adults. Good synergy with your framework.
41	Yes	Yes	Yes	Yes (J Cross-Cultural Gerontol.)	Yes	High	Comparison of environmental challenges in Japan & Sweden. Peer-reviewed.
42	Yes	Yes	Yes	Yes (IJERPH)	Yes	High	Explores living environment/thermal behavior among older adults in Australia.
43	Yes	Yes	Yes	Yes (AVI Conf. Proc.)	Yes	High	Focus on empowerment goals in elderly-centered interaction design.
44	Yes	Yes	Yes	Yes (IJERPH)	Yes	High	Kitchen layout for aging-friendly environments using space syntax.
46	Yes	Yes	Yes	Yes	Yes	High	Provides humanization-based strategies for aging-friendly home spaces.

Appendix B

Appendix B1. Coding of Challenges

Below is a comprehensive table illustrating how various references contributed to identifying challenges older adults face in aging-in-place contexts. Each row identifies a specific Code (e.g., “Narrow Corridors and Doorways”), includes a brief Description, References that mention or support that code, and the Broader Theme under which the code is grouped.

Table A2. Challenges Coding and Thematic Grouping.

Code	Description/Key Points	Relevant References	Broader Theme
Narrow Corridors and Doorways	Corridors/doorways too tight for wheelchairs or walkers, creating fall risks and restricting free movement.	[1,14,18,28]	Physical Barriers & Lack of Ergonomic Adaptability
High Fixtures & Limited Reach	Kitchen/bathroom fixtures are too high, forcing older adults to stretch or climb.	[18,29,34,35,44]	Physical Barriers & Lack of Ergonomic Adaptability
Poor Lighting & Glare	Inadequate or poorly calibrated lighting for age-related vision changes; can cause falls, depression, disorientation.	[4,14,17,24,29,36]	Poor Lighting & Reduced Visual Accessibility
Lack of Natural Light/Biophilia	Insufficient daylight, minimal greenery, limited windows/balconies,	[15,17,24,31,32,42]	Limited Biophilic Integration

	depriving older adults of beneficial nature experiences that reduce stress and boost cognition.		
Spatial Complexity & Wayfinding	Repetitive layouts, few visual cues or landmarks, and unclear circulation hamper navigation—especially for mild cognitive impairments.	[1,12,28,30]	Ineffective Wayfinding & Spatial Organization
Limited Cognitive Accessibility	Spaces or layouts not designed for mild cognitive impairment (lack of color contrasts, memory cues, or clarity).	[2,3,12,13,25]	Ineffective Wayfinding & Spatial Organization
Complicated Smart-Home Interfaces	Interfaces (sensors, apps, panels) may be unintuitive, with small text or confusing workflows, making it hard for older adults to engage with IoT solutions.	[6–9,14,16,22,23]	Technology & Usability Gaps
Privacy & Adoption Barriers	Continuous monitoring devices may feel intrusive; fear of data misuse or cultural resistance to unfamiliar tech.	[1,19,22,32,33,38,40]	Technology & Usability Gaps
Cost & Funding Gaps	Financial limitations prevent homeowners from retrofitting or adopting new technologies; also a lack of affordable solutions for older adults.	[14,26,27,39,40]	Socioeconomic & Policy-Related Barriers
Inadequate Training & Workforce Skills	Insufficient professional training in “design for aging,” plus older adults who lack guidance on new devices or universal design features.	[1,10,12,37,40]	Socioeconomic & Policy-Related Barriers
Environmental Press vs. Competence	Mismatch between older adults’ functional abilities and the demands (press) of the environment can reduce autonomy and well-being.	[13,14,20,21]	Mismatch in Person–Environment Fit

Appendix B2. Coding of Solutions

This second table focuses on how the references address solutions or interventions to mitigate the challenges above. Each row shows a Code, Description, References, and the Broader Theme (e.g., Universal Design, Biophilic Integration, Technology, or Policy).

Table A3. Solutions Coding and Thematic Grouping.

Code	Description/Key Points	Relevant References	Broader Theme
Universal/Inclusive Design	Designing environments that accommodate all abilities from the start—lever handles, zero-threshold doors, adjustable counters, etc.	[10,12,23,37,41,46]	Universal & Human-Centered Design
Co-Creation & Participatory Design	Involving older adults in design decisions via focus groups, prototypes, user feedback loops, ensuring interventions match actual needs and preferences.	[1,13,28,43]	Universal & Human-Centered Design

Adjustable Fixtures & Ergonomics	Ergonomic improvements (height-adjustable sinks, slip-resistant floors, handheld showerheads, etc.) that reduce fall risk and accommodate varied mobility.	[1,28,29,35,44]	Physical Adaptation
Enhanced Lighting (Dynamic/Circadian)	Systems that automatically adjust brightness/color temperature throughout the day to support circadian rhythms and improve older adults' safety and comfort.	[4,14,17,24,34,36,38]	Physical Adaptation
Biophilic Design Strategies	Incorporating natural elements (greenery, daylight, natural materials) and indoor-outdoor connections to reduce stress, enhance cognition, and improve well-being.	[15,17,24,28,31,32,42]	Biophilic Integration & Sustainability
Sustainable Material Selection	Using low-VOC paints, recycled materials, LED lighting, and energy-efficient systems to promote environmental health and occupant well-being, while reducing operational costs.	[1,26,27,30,31]	Biophilic Integration & Sustainability
Ambient Assisted Living (AAL) & IoT	Sensor-based solutions (fall detection, motion sensors, wearable devices) and smart-home systems for remote health monitoring, safety alerts, and daily convenience.	[6–9,19,22,33,38–40]	Technology Integration
User-Friendly Interfaces	Large fonts, intuitive icons, voice controls, minimal complexity, plus training to help older adults and caregivers comfortably adopt new technologies.	[2,3,8,9,14,19,23,32]	Technology Integration
Wayfinding Enhancements	Clear signage (large fonts, contrasting colors), tactile cues, color zoning, intuitive layouts to aid navigation (especially for mild cognitive impairment).	[1,12,25,28,30]	Spatial Organization & Wayfinding
Policy & Funding Incentives	Grants, tax credits, or updated building codes that encourage universal design features, retrofitting older homes, or subsidizing smart-tech installation.	[1,10,26,27,30,32]	Implementation & Policy

Multidisciplinary Collaboration	Collaboration among architects, gerontologists, occupational therapists, engineers, etc. to ensure age-friendly designs meet physical, cognitive, and emotional needs.	Implementation & Policy
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