

Development of a Human-Centric Smart and Adaptive Interior Design Framework (SAIDF) for Ageing-in-Place

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Abstract: As the world has continued to age, the need for residential settings that facilitate safe, independent and healthy ageing in place has grown. Currently, however, conventional housing does not take into account the physical, cognitive and sensory changes of ageing, and current smart home and interior design solutions are disjointed. This study aims at developing a Human-Centric Smart and Adaptive Interior Design Framework (SAIDF) based on principles of universal design, smart technologies, environmental psychology, ergonomic planning, biophilic design and human-centered design and combining them in a conceptual framework. The framework was created by a thorough review and synthesis of the latest literature on smart living, gerontology, interior design, and architecture. The six components of SAIDF are: human-centric user assessment, smart adaptive technologies, universal and ergonomic interior design, environmental psychology and biophilic design, participatory co-design and continuous monitoring with adaptive feedback. Together, they offer a structured framework to follow in the development of adaptive residential environments that address the changing needs of older people. The proposed framework supports the inclusion of interior design and intelligent technologies and provides concrete recommendations for architects, interior designers, researchers and policy makers to create a safe, independent and ageing-friendly home environment.

Keywords: Aging-in-place; Smart Interior Design; Human Centric Design; Universal Design; Elderly Care

Introduction

Population ageing is one of the biggest demographic changes of the 21st century, presenting new challenges for the built environment, housing and health care systems.[1] [2] By approximately 2050, the World Health Organization (WHO) estimates that there will be around 2.1 billion people in the world aged 60 years and older.[1] With the aging of the population, there is a need to develop residential settings which provide older adults with autonomy, security, comfort, and enjoy a good quality of life, while maintaining their physical, cognitive and emotional health.[2] Ageing-in-place (AiP) is becoming a preferred option where older persons live at home and in their communities, instead of moving into institutional care.[3] Residents in familiar surroundings enjoy autonomy, social connections and psychological health; they see a decrease in healthcare expenses, and an increase in overall quality of life. [3] Yet, a number of current homes were built without taking into account how older resident's age. Falls risks are higher with poor lighting, layouts, slippery floors, non-ergonomic furniture, and poor space utilization and mobility is also reduced and independence is reduced. [3]With the recent developments of smart home technologies new

opportunities have emerged to enhance the quality of residential environments for elderly persons. The Internet of Things (IoT), intelligent sensors, automated lighting systems, voice-controlled interfaces, and environmental monitoring systems are among the technologies that can improve safety, access and comfort by meeting the needs of users in real time. Meanwhile, the principles of universal design, ergonomic design, environmental psychology, and biophilic design have been shown to enhance the inclusive and supportive nature of living spaces. [5], [6], [7] However, most of these strategies have been applied separately, creating disjointed solutions that don't always tackle the multifaceted and dynamic requirements of ageing populations.[7], [8] There is a research gap in the absence of an integrated framework that brings together the human-centered design, smart technologies, and adaptive interior planning. Previous research has been conducted at the level of technology or accessibility of buildings, but a systematic approach to their integration in interior design has been largely overlooked. Thus, a comprehensive design approach that can help designers to build smart homes that are adaptable, user-centred and responsive to the physical, cognitive and emotional needs of older people is still needed.[7], [8], [9] Based on this, this study attempts to fill this gap by proposing a Human-Centric Smart and Adaptive Interior Design Framework (SAIDF) for ageing-in-place. The core of the proposed framework is the conceptual inclusion of universal design principles, smart technologies, environmental psychology, ergonomic planning, biophilic design and participatory human-centered design in a single framework. [9] SAIDF emphasizes the necessity of incorporating the perspectives of older adults in designing safe, accessible homes that enhance their independence and quality of life. It presents an interdisciplinary framework for planners, architects, and researchers that draws on ageing-friendly design. Additionally, it advocates for integrating intelligent technologies with interior design to create sustainable, adaptive housing for aging populations.

Related work

During the last 20 years, this idea of Ageing-in-Place (AiP) has been a hot topic for research and discussion related to supporting older adults in independent living. [5] [6]Initial research was mainly targeted on providing barrier-free residential settings using principles of Universal Design (UD), which were aimed at accessibility, safety, and utility of people with different physical characteristics.[5] Although these studies enhanced the accessibility of residential premises, they neglected technological adaptability and personalization of the user.[5] As digital technologies have advanced, smart home systems have been introduced in homes to enhance safety and health monitoring.[10] IoT-based sensors, smart lighting, fall detectors and automation of the environment have shown great potential in the realm of supporting elderly individuals and improving their quality of life and easing caregiver dependency.[2] [10]Most studies conducted with technology, however, focus on system performance and automation and neglect aspects of interior space quality, ergonomics and psychological well-being for occupants.[10] In recent years, the value of Human-Centered Design (HCD) and Environmental Psychology (EP) in developing and designing age-friendly living environments has increasingly been shown. [7]These methods emphasize the importance of focusing spaces on users' physical, cognitive and emotional requirements and

encourage users to be involved in design. Likewise, in residential interior applications, the use of natural light, greenery, and nature-themed materials has been proven to positively impact mental health. Most of these studies, however, focus on the quality of the environment without addressing smart technologies. A number of researchers have tried to merge smart technologies with universal design to build an adaptive residential environment. While these integrated approaches are important steps forward, most are concerned with engineering solutions for the building and do not have a complete interior design guideline. In addition, little focus has been placed on participatory co-design, personalization and adaptive feedback over time which are central to addressing evolving needs of older adults. The literature review shows that, there are still many fragmented studies where studies focus on each aspect individually related to accessibility, automation, ergonomics, environment quality etc. Creating a unified design methodology systematically integrating these components is clearly needed to provide an interdisciplinary framework. In view of this, this study suggests the Human-Centric Smart and Adaptive Interior Design Framework (SAIDF) by integrating the concepts of universal design, smart adaptive technology, environmental psychology, ergonomic planning, biophilic design and participatory co-design in one conceptual framework for ageing-in-place.

Table 1. Comparison of Related Studies with the Proposed SAIDF Framework

Study	Universal Design	Smart Technologies	Human - Centered Design	Environmental Psychology	Biophilic Design	Integrated Framework
[1] Universal Design for Ageing	✓	✗	✓	✗	✗	✗
[2] Smart Home for Elderly Care	✗	✓	✗	✗	✗	✗
[3] Human-Centered Design Approach	✓	✗	✓	✓	✗	✗
[4] Biophilic Interior Design	✗	✗	✓	✓	✓	✗
[5] IoT-based Assisted Living	✓	✓	✗	✗	✗	✗
This Work (SAIDF)	✓	✓	✓	✓	✓	✓

Key Contribution

This research introduces the Human-Centric Smart and Adaptive Interior Design Framework (SAIDF), aimed at enhancing ageing-in-place strategies. This framework integrates universal design, smart home technologies, environmental psychology, ergonomics, and biophilic design, with a focus on meeting the needs of elderly users. SAIDF promotes accessibility,

adaptation to technology, and positive psychological outcomes, emphasizing the importance of co-design and adaptive feedback for evolving residential environments. It serves as a resource for architects, designers, researchers, and policymakers to cultivate user-friendly and responsive spaces for ageing individuals.

Method, Experiments and Results

The study presents the Human-Centric Smart and Adaptive Interior Design Framework (SAIDF), aimed at creating adaptive residential environments for older adults. Unlike traditional methods, SAIDF centers on elderly users as design originators and integrates smart technologies to create responsive living spaces. The framework comprises six interconnected components focusing on accessibility, safety, comfort, and psychological well-being, beginning with Human-Centric User Assessment to identify user needs. It employs Smart Adaptive Technologies such as IoT sensors and ergonomic design, while also incorporating Environmental Psychology and Biophilic Design to support mental health. Participatory Co-design enhances technology acceptance, and Continuous Monitoring allows for adaptation over time. This integrated framework offers architects and designers practical guidance for developing inclusive homes that promote healthy aging.

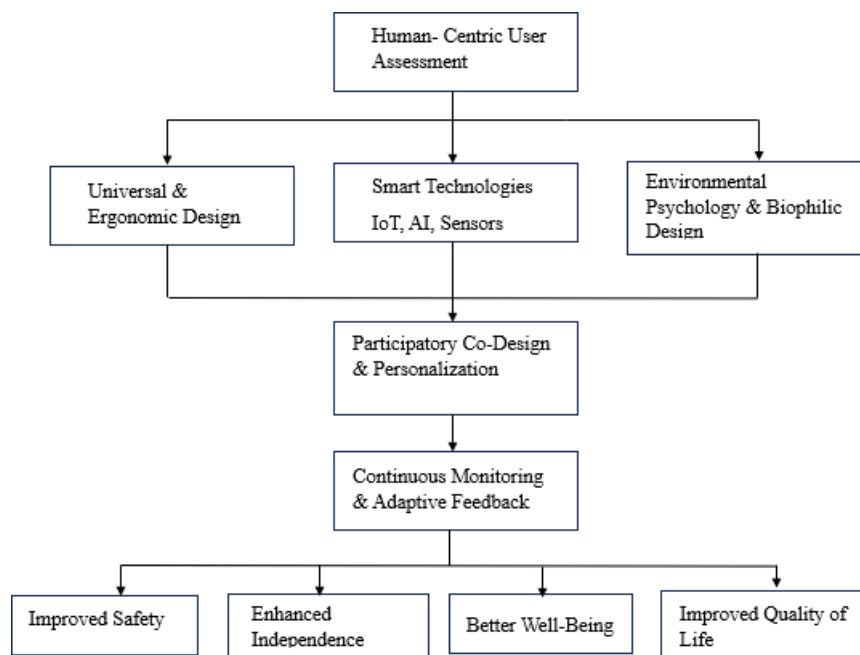


Figure 1. Human-Centric Smart and Adaptive Interior design Framework (SAIDF).

Discussions

The Human-Centric Smart and Adaptive Interior Design Framework (SAIDF) addresses a significant gap by merging interior design principles with smart technologies, aimed at enhancing the ageing-in-place experience. It emphasizes a user-centered approach, prioritizing the preferences and needs of elderly users over purely technology-driven solutions. SAIDF promotes interdisciplinary collaboration among designers, caregivers, and

healthcare professionals to create environments that cater to the evolving physical and cognitive requirements of older adults. The framework integrates smart technologies, ergonomic design, and environmental psychology to foster independence, safety, and comfort in residential settings. By viewing the home as an adaptive system rather than just a physical space, SAIDF allows for continuous adjustment to users' changing abilities, thereby enhancing their quality of life. This conceptual model lays the groundwork for future studies and practical applications in creating ageing-inclusive environments, underscoring the necessity of integrating human-centered design with supportive technologies for successful ageing in place.

Conclusions

This research addresses a gap in interior design for ageing-in-place, highlighting that existing residential environments and smart home solutions often fail to meet older adults' diverse needs. Utilizing a qualitative conceptual research method, the study introduces a Human-Centric Smart and Adaptable Interior Design Framework (SAIDF), derived from a comprehensive literature review encompassing universal and human-centered design, smart technologies, environmental psychology, ergonomics, and biophilic design. The SAIDF consists of six interconnected components: human-centric user assessment, smart adaptive technologies, universal design, ergonomic design, participatory co-design, and continuous monitoring with adaptive feedback. This framework aims to create adaptive residences that enhance safety, accessibility, independence, and quality of life for older adults. Future research is needed to empirically test the framework through expert reviews, case studies, prototype implementations, and Post-Occupancy Evaluations to validate its effectiveness in real residential settings.

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