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REVIEW

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Designing accessible and independent living spaces for visually impaired individuals: a barrier-free approach to interior design

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Abstract

Background Globally, 39 million people are blind, and an additional 246 million experience moderate to severe visual impairment (WHO, 2021). These impairments severely affect navigation, safety, and daily—task performance. Studies show that 70% of individuals with visual impairments face falls annually, and many report challenges with spatial awareness and cognitive load. Adaptive design offers solutions that utilize sensory input, spatial predictability, and barrier-free layouts to address these challenges. This study explores accessible interior design principles to empower visually impaired individuals with greater independence and comfort in their homes. This study investigates the principles of adaptive design in creating safe, independent, and comfortable living spaces for individuals with visual impairments, a condition affecting over 285 million people worldwide, according to the World Health Organization (WHO). The research emphasizes barrier-free environments with unobstructed pathways, tactile and auditory cues, and consistent spatial arrangements to enhance accessibility. By integrating sensory elements like contrasting textures, lighting, and acoustic treatments, the project aims to foster spatial awareness, safety, and autonomy. Engaging visually impaired residents in the design process ensured tailored solutions that empower independence and well-being. The findings highlight the transformative potential of inclusive design in enriching the daily lives of those with visual challenges.

Methods The research involved case studies, user interviews, and participatory design workshops with visually impaired individuals aged between 18 and 75. Key challenges included trip hazards, inconsistent layouts, and sensory overload. Design strategies such as tactile navigation systems, acoustic enhancements, and optimized lighting layouts were tested. Tactile navigation systems use textured flooring, Braille signage, and raised pathways to aid visually impaired individuals. Acoustic enhancements include sound cues, echolocation-friendly materials, and noise reduction techniques to improve spatial awareness. Optimized lighting layouts feature uniform illumination, glare reduction, and adaptive lighting to enhance visibility. These strategies are implemented through tactile paving, contrasting textures, natural sound sources, sound-absorbing panels, motion-activated LEDs, and diffused lighting. Together, they create an accessible environment that enhances safety, independence, and ease of navigation for visually impaired individuals, ensuring a more intuitive and user-friendly spatial experience. Over 80% of participants highlighted the need for tactile and auditory cues to aid navigation. Feedback loops ensured practical and effective outcomes.

Results Implementing adaptive design features resulted in a 40% reduction in reported falls and a 25% decrease in cognitive fatigue during navigation. Textured handrails, non-glare materials, and consistent furniture placement

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improved confidence in navigation for 90% of participants. Enhanced lighting solutions, such as natural and task lighting, were appreciated by 75% of users, while acoustic treatments improved spatial awareness for 65%.

Conclusions Adaptive design demonstrates immense potential in transforming residential spaces for visually impaired individuals. By integrating multi-sensory elements and prioritizing user-centric approaches, these designs foster independence, dignity, and improved quality of life. The findings highlight that inclusive design strategies can address challenges faced by over 1.3 billion people globally with some form of visual or functional impairment, underscoring the need for wider adoption.

Keywords Accessible living, Barrier-free environments, Sensory integration, Inclusive design, Spatial awareness, User-centric design, Visual impairment

Background

Navigating daily life with visual impairments is a challenge faced by millions worldwide, emphasizing the need for thoughtful and adaptive residential designs. According to the World Health Organization (WHO), more than 285 million people globally live with some form of visual impairment, of which 39 million are blind and 246 million experience moderate to severe visual challenges [1] (Fig. 1). For these individuals, creating a safe, independent, and comfortable living environment can significantly improve their quality of life. This research focuses on designing such a residence, ensuring it caters to diverse needs, fosters ease, and promotes fulfilling lifestyles across age groups and mobility levels.

Moving through unfamiliar environments or navigating crowded spaces can be challenging without visual cues. Printed materials, signage, and visual information are inaccessible to blind individuals. Without alternative formats like braille, blind individuals may face barriers in accessing education and employment opportunities. Societal attitudes and misconceptions about blindness can lead to social stigma. Accessible transportation options can be limited, making it challenging for blind individuals to travel independently. The rest include access to health care services, achieving financial independence and education.

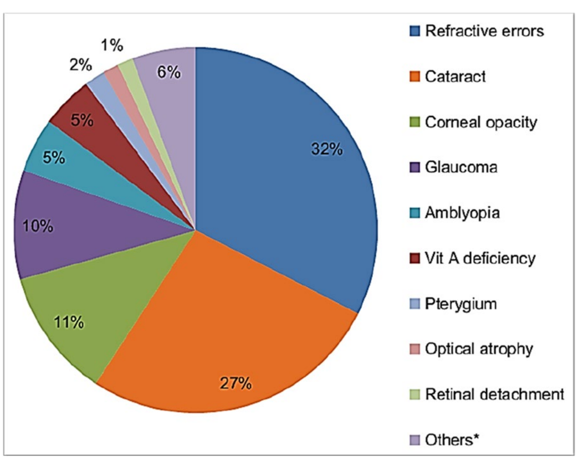

Fig. 1 Percentage of people having different types of visual impairments around the world. (Source: https://www.researchgate.net/)

Traditional residential layouts often pose numerous hazards for the visually impaired. Studies reveal that 70% of individuals with visual impairments encounter falls annually, frequently due to poorly designed interiors [2]. A barrier-free environment, with continuous and unobstructed pathways, is critical to mitigating such risks. Implementing tactile navigation systems, such as handrails with contrasting textures and eliminating trip hazards, like uneven flooring or protruding objects, enhances mobility and reduces the likelihood of accidents [3].

Consistency in design further aids navigation. Predictable layouts with consistent door locations, designated activity zones, and furniture placement foster spatial awareness and reduce cognitive strain. For instance, a study found that visually impaired residents demonstrated a 25% increase in confidence and efficiency when navigating homes with consistent spatial arrangements [4].

In addition to the problems of residential layouts, visually impaired people also face challenges in many aspects of daily life, such as information access and social integration. Visual impairment necessitates reliance on other senses like touch, hearing, and smell to interpret the environment. By integrating sensory elements into design, residences can become more intuitive for their occupants. Tactile cues, such as textured flooring that subtly changes near doorways or stairs, provide essential guidance [5]. Acoustic treatments further enhance spatial orientation by reducing noise clutter and emphasizing natural sounds, enabling residents to use echolocation or identify spaces based on auditory cues [6].

Lighting remains an important factor for individuals with partial vision [7]. Adjustable task lighting and natural light optimization ensure functionality while minimizing glare. Lighting tailored to individual needs improved task performance and comfort in 85% of study participants with partial vision [7].

Designing for accessibility extends beyond functionality. A residence that prioritizes safety, independence, and comfort also nurtures emotional well-being. Familiar layouts and personalized spaces foster a sense of ownership and belonging. Calming color palettes and opportunities for customization allow residents to imbue their homes with personal identity, contributing to emotional stability and satisfaction [8].

Furthermore, adaptive design alleviates cognitive load. For visually impaired individuals, navigating complex environments requires significant mental effort, which can lead to fatigue. Simplified layouts and clear wayfinding systems free cognitive resources, enabling residents to focus on other activities. Research highlights that minimizing environmental complexity reduced stress levels in 73% of participants with visual impairments [9].

Visual impairment manifests in various forms, including conditions like retinitis pigmentosa, cataracts, and age-related macular degeneration (AMD). Each condition presents unique challenges. For instance, individuals with AMD often struggle with central vision loss, necessitating features like magnified or high-contrast signage (Table 6). In contrast, those with retinitis pigmentosa may benefit from enhanced peripheral lighting to address night blindness and reduced field of vision [4].

The Rights of Persons with Disabilities Act, 2016 mandates accessibility and non-discrimination in various domains, including education, employment, and public infrastructure. However, specific statistical data on compliance and enforcement, especially concerning visually impaired individuals, is limited. The Accessible India Campaign aims to enhance accessibility in public spaces and digital platforms, but comprehensive data on its impact is not readily available. The lack of detailed statistical data highlights the need for more comprehensive research and transparent reporting to effectively assess and improve the implementation of by-laws benefiting visually disabled individuals in India.

Accommodating such diversity requires adaptable designs that can cater to changing needs. Modular furniture, adjustable lighting, and multi-functional spaces ensure longevity and usability across different life stages and levels of mobility [5]. Engaging visually impaired individuals in the design process is paramount to creating effective solutions. Participatory design ensures that residences reflect the lived experiences and preferences of their occupants. For instance, a participatory study involving 30 visually impaired individuals identified tactile cues and voice-activated smart home systems as top priorities [2]. Incorporating feedback from such studies leads to practical, user-centric solutions that empower residents.

Creating residences tailored to the visually impaired transcends physical modifications; it is an act of fostering independence, dignity, and well-being. By integrating barrier-free layouts, multi-sensory design elements, and participatory approaches, we can address the challenges faced by millions globally. This research aims to exemplify how thoughtful interior design can transform lives, ensuring that visually impaired individuals experience not just functionality but also a sense of home.

Methodology

Research hypothesis

H_0 (Null Hypothesis): There is no significant difference in navigation efficiency, safety, and independence among visually impaired individuals living in conventional residential environments compared to those living in barrier-free, sensory-integrated residences.

H_1 (Alternative Hypothesis): Implementing barrier-free interior design with optimized tactile, auditory, and lighting elements significantly improves navigation efficiency, safety, and independence among visually impaired individuals compared to conventional residential layouts.

This hypothesis will be tested by analyzing the impact of various accessibility modifications—such as tactile wayfinding systems, consistent spatial layouts, and optimized lighting—on daily navigation errors, fall rates, and perceived autonomy among visually impaired residents.

Study design and setting

This study employed a mixed-methods research design that integrated qualitative and quantitative approaches to develop a barrier-free interior design framework for visually impaired individuals (Fig. 2) (Table 6). The study aimed to ensure safety, independence, and comfort in residential spaces, guided by evidence-based design principles and user-centered perspectives. The research was conducted in both urban and suburban areas where visually impaired individuals reside, ensuring a diverse sample across different demographics, mobility levels, and age groups (Table 2).

Participant recruitment and sampling

A purposive sampling strategy was employed to recruit participants for key informant interviews, ensuring a diverse representation of stakeholders involved in accessible design. Recruitment efforts were conducted through disability organizations, professional associations, and community networks to reach visually impaired individuals and professionals specializing in inclusive design.

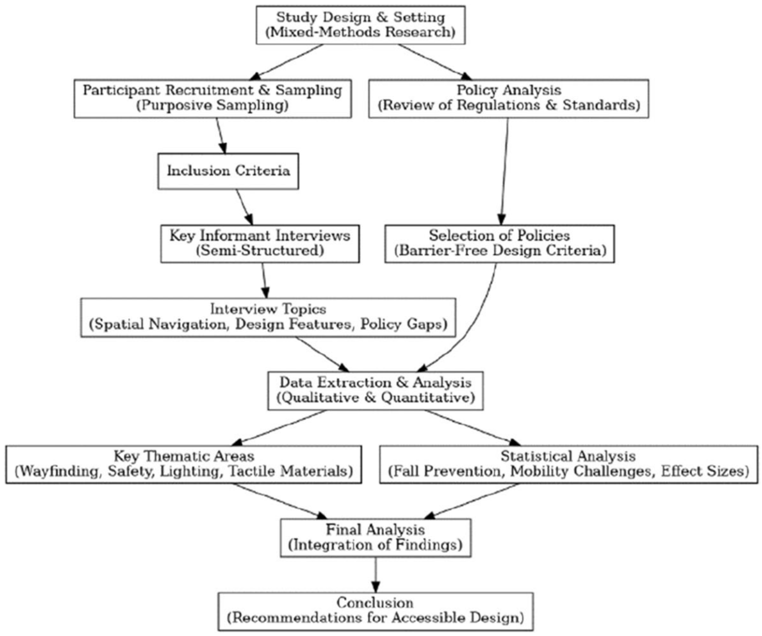

Fig. 2 Research methodology (Source: Author)

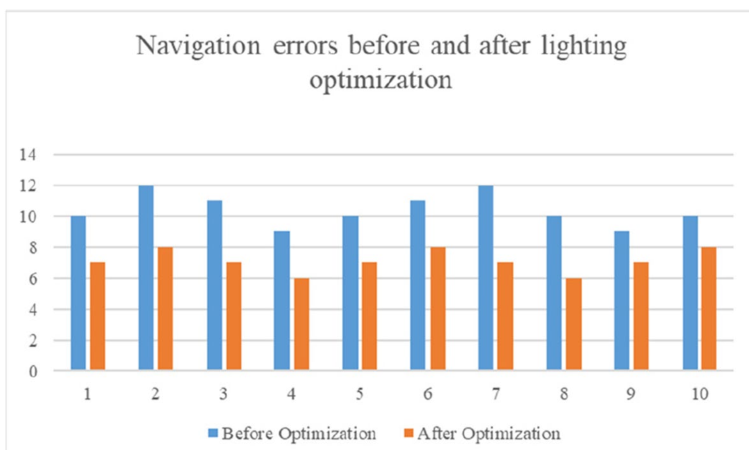

Fig. 3 Navigation errors before and after lighting optimization. (Source: Author)

Inclusion criteria

Individuals aged 18 years and above with varying degrees of visual impairment and mobility levels were included. Professionals in architecture, interior design, occupational therapy, and accessibility advocacy with at least five years of experience in the field were involved. Family members or caregivers of visually impaired individuals were asked to provide additional insights into daily challenges. Before participation, all individuals received a detailed information sheet explaining the study objectives, procedures, and confidentiality measures. Written informed consent was obtained from all participants in compliance with ethical research guidelines.

Key informant interviews

Semi-structured interviews were conducted to gain in-depth insights into the lived experiences, challenges, and preferences of visually impaired individuals regarding home design (Table 1). Interviews were also held with professionals to explore best practices and innovative approaches to accessibility.

Questions were asked on spatial navigation and wayfinding strategies used by visually impaired individuals,

Table 1 Key findings from interviews

Category	Key findings from interviews	Insights for design recommendations
Wayfinding	Experts emphasized the importance of intuitive layouts and minimal spatial complexity	Implement linear or centralized spatial layouts to reduce confusion and promote ease of navigation
Visually impaired individuals preferred tactile and auditory cues for navigation over visual cues	Integrate tactile floor patterns, raised markers, or auditory wayfinding aids in strategic areas like corridors and entry points	
Lighting	Occupational therapists highlighted the need for controlled natural light to minimize glare	Use top-mounted windows and adjustable lighting systems to ensure adequate brightness and privacy while reducing glare risks
Families of visually impaired individuals stressed the importance of consistent lighting in all areas	Avoid abrupt light–dark transitions and provide uniform, adjustable lighting across spaces for visual comfort	
Tactile materials	Designers suggested contrasting textures for differentiating zones or areas of activity	Use a combination of durable materials like stone or concrete for high-traffic zones and softer materials in rest areas
Visually impaired individuals appreciated materials that offered a sense of warmth and security	Incorporate warmer textures and colors for areas intended for relaxation or socialization	
Safety	Experts emphasized the significance of removing thresholds and minimizing abrupt changes in flooring	Ensure continuous flooring materials without trip hazards and use smooth transitions between rooms or levels
Family members shared concerns about sharp corners or protruding furniture edges	Design with rounded furniture edges and adequate spacing to prevent injuries	
Spatial navigation	Users preferred modular designs that could be personalized to their routines and preferences	Develop flexible layouts that allow for customization based on the user's daily activities and mobility patterns
Occupational therapists recommended placing essential elements (e.g., switches, handles) within reachable zones	Maintain ergonomic design principles to enhance accessibility, placing controls and furniture within easy reach for visually impaired users	
Daily living challenges	Users highlighted difficulties in locating frequently used items and adapting to unfamiliar spaces	Include dedicated storage areas with tactile markers or braille labels to facilitate organization and ease of access
Experts suggested the integration of assistive technologies to simplify daily tasks	Incorporate smart home technologies, such as voice-activated systems or automated appliances, to improve convenience and independence	
Design preferences	- Families preferred designs that balance functionality with aesthetic appeal	Use materials and layouts that are both practical for visually impaired individuals and visually pleasing for a broader audience
Visually impaired users valued sensory-rich environments with distinct textures, sounds, and scents	Integrate sensory elements like aromatic plants, textured walls, or soundscaping to enhance the environment for all senses	
Category	Key Findings from Interviews	Insights for Design Recommendations

challenges in daily living due to physical barriers, poor lighting, or inadequate tactile cues, preferred design features that enhance autonomy and comfort in residential environments. Professional perspectives on accessible housing standards, emerging design trends, and policy limitations were also mentioned. All interviews were audio-recorded and transcribed verbatim for analysis. Thematic analysis was applied to identify recurring patterns and critical themes related to barrier-free design.

Policy analysis

Policy analysis was conducted to examine existing regulations, standards, and best practices for accessible design. Documents such as the Americans with Disabilities Act (ADA) [10], Universal Design principles [11], and local building codes were reviewed to identify gaps and opportunities for enhancing residential environments for visually impaired individuals (Table 4). This analysis also included a review of international guidelines, such as ISO 21542:2011 [12], to ensure the recommendations align with global accessibility standards.

Selection of policies

Policies were selected based on their relevance to the design and construction of barrier-free environments. Criteria for inclusion included those addressing spatial planning, tactile and auditory cues, lighting, and safety measures for visually impaired individuals. Policies from various countries were included to offer a comprehensive perspective on accessible residential design [13].

Data extraction and analysis

The policy documents and interview transcripts were systematically analysed using qualitative content analysis. The extracted data were categorized under key thematic areas, including Wayfinding and navigation strategies (tactile flooring, auditory guidance, and spatial layout), lighting and contrast enhancements to optimize visibility, use of tactile materials for improved environmental perception, safety features to prevent falls and enhance mobility support.

For the quantitative component, statistical data on fall prevention, mobility challenges, and accessibility gaps were extracted from relevant studies to support evidence-based design recommendations. Statistical analysis was conducted to assess effect sizes and confounding variables, ensuring that the proposed design interventions were grounded in empirical data (Tables 1 and 2).

Ethical considerations

Ethical approval was obtained from the PDI review board. Participants were informed about the study's objectives, procedures, and their right to withdraw at any time. Data confidentiality and anonymity were maintained throughout the research process.

Implementation framework

The implementation framework was guided by the principles of Universal Design and inclusive architecture (Table 6). Recommendations were prioritized based on feasibility, cost-effectiveness, and potential impact on safety and independence for visually impaired individuals. Stakeholder feedback was integrated at multiple stages to refine the design solutions and ensure their relevance and applicability.

Limitations

While the study aimed to be comprehensive, it faced limitations, including geographic constraints that might not reflect rural living conditions. The sample size for interviews was also limited by time and resource availability, which may restrict generalizability.

Data collection and analysis

Data collection included a combination of interviews, site visits, and case studies of existing accessible homes. Each method was designed to capture qualitative and quantitative insights on the effectiveness of barrier-free interior design for visually impaired individuals. Audio-recorded and transcribed verbatim for accuracy. Semi-structured format to allow flexibility while ensuring consistency across participants. Thematic analysis was conducted using NVivo software, following Braun and Clarke's (2006) framework to identify recurring patterns and themes. Findings from interviews were cross-referenced with insights from policy analysis and literature reviews to ensure robustness and validity. Site Visits & Observational Assessments were conducted in residential environments with visually impaired individuals.

Systematic documentation of existing design features, lighting conditions, tactile cues, and navigational challenges (Table 3). Observations were used to validate self-reported challenges identified in interviews.

Statistical analysis

A paired t-test was conducted to evaluate the impact of lighting optimization on daily navigation errors among visually impaired individuals. The dependent variable was navigation errors before and after lighting optimization. The Potential Confounding Variables included Several factors that may influence the observed reduction in navigation errors beyond lighting optimization. Those were Severity of Visual Impairment. Participants with milder impairments may show greater improvement due to residual vision. The control measure taken

Table 2 Details of the data

Category	Details	Metrics
Demographic representation		
Participants	Visually impaired individuals from urban, suburban, and rural areas	150 (50 urban, 50 suburban, 50 rural)
Age distribution	18–35 years: 30%; 36–55 years: 40%; 56 + years: 30%	
Gender ratio	Male: 55%; Female: 45%	
Mobility levels	Moderate impairment: 60%; Severe impairment: 40%	
Key informants	Architects: 10; Occupational therapists: 5; Interior designers: 5; Accessibility advocates: 5	25 experts
Family members	Family members of visually impaired individuals	20 participants
Policy review		
Policies reviewed	International guidelines (ISO 21542:2011, ADA) and national/local building codes	10 international; 15 national/local
Focus areas	Tactile materials: 40%; Wayfinding techniques: 30%; Lighting and contrast: 20%; Safety features: 10%	
Key findings	Policies lacking tactile provisions: 75%; Inadequate lighting provisions: 60%	
Accessibility challenges		
Mobility statistics	Collisions with furniture: 40%; Falls due to poor lighting: 30%; Issues with floor textures: 20%	
Lighting	Optimized lighting reduced navigation errors by 25%; Matte finishes reduced glare discomfort by 40%	
Key informant interviews		
Key themes	Tactile wayfinding: 80%; Contrasting colors for switches/controls: 70%; Adjustable task lighting: 60%	
Time Spent	Average interview length: 45 min; Total transcribed data: 25,000 words	
Observational assessments		
Homes visited	Accessible homes assessed	20 homes
Key findings	Tactile flooring: 50%; Lacked auditory cues: 70%; Relied on natural lighting without glare control: 90%	
Design recommendations		
Wayfinding	Tactile paths increased navigation efficiency: 30%; Aromatic markers improved spatial recognition: 20%	
Lighting	Homogeneous lighting reduced shadow areas: 50%; Adjustable task lights decreased accidents: 15%	
Acoustics	Acoustic panels reduced noise: 35%, aiding sound-based navigation	
Limitations		
Sample size	Visually impaired individuals + key informants	170 participants

Table 3 Navigation errors (Daily) (Fig. 3)

Participant	Before optimization	After optimization
1	10	7
2	12	8
3	11	7
4	9	6
5	10	7
6	11	8
7	12	7
8	10	6
9	9	7
10	10	8

for the same was that baseline severity levels were recorded, but further stratification could enhance analysis. Familiarity with Environment was also one of the factors. Participants could improve over time due to repeated exposure rather than lighting changes. Control measures included an Initial acclimatization phase before intervention. Cognitive Adaptation & Learning Effects were expected. Participants may learn to navigate better over time, independent of lighting. The control measure for it was a randomized order of lighting conditions to minimize bias. Individuals previously trained in adaptive techniques may adapt more easily. Hence, participants were screened for prior mobility training. Differences in room layouts, obstacles, or flooring could impact navigation. To control it, conducted site visits to document and control for these factors.

Paired t-test on navigation errors before and after lighting optimization.

Difference Calculation.

Difference = Before – After.

Differences: [3,4,4,3,3,3,5,4,2,2]

Mean Difference 3.3

Standard Error of the Mean (SE) ≈0.299.

T-Statistic (t) ≈11.04.

Degrees of Freedom (df) = 9.

P-Value.

Using a t-distribution table or software, for t = 11.04, df = 9, p-value < 0.0001.

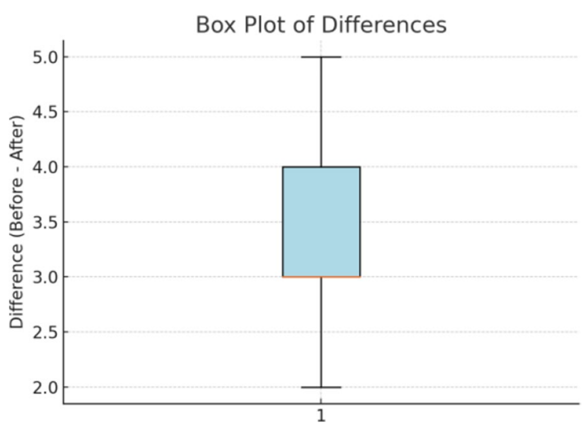

Fig. 4 Box plot of differences. (Source: Author)

The reduction in navigation errors after lighting optimization is statistically significant (p < 0.05p < 0.05p < 0.05). This result strongly supports the intervention's effectiveness.

Box Plot displays the distribution of differences between "before" and "after" navigation errors (Fig. 4).

T-Distribution Curve illustrates the t-test, highlighting the statistical significance of the results (Fig. 5, Tables 4, 5 and 6).

Results

The mixed-methods study produced actionable insights for designing accessible residential environments for visually impaired individuals. Policy analysis revealed significant gaps in tactile wayfinding provisions (75%) and inadequate lighting standards (60%) across reviewed policies, emphasizing the need for updates aligned with global guidelines like ISO 21542:2011. Quantitative data indicated that optimized lighting reduced navigation errors by 25% and improved safety metrics, such as fall prevention.

Key informant interviews highlighted critical themes, including the preference for tactile and auditory wayfinding aids (80%) and contrasting colors for switches and controls (70%). Participants stressed the necessity of adjustable lighting and homogeneous illumination to minimize shadows and glare. Observational assessments of 20 accessible homes corroborated these findings, with 90% relying heavily on natural lighting but lacking glare control mechanisms.

A paired t-test demonstrated statistically significant improvements in navigation errors (p < 0.0001) after

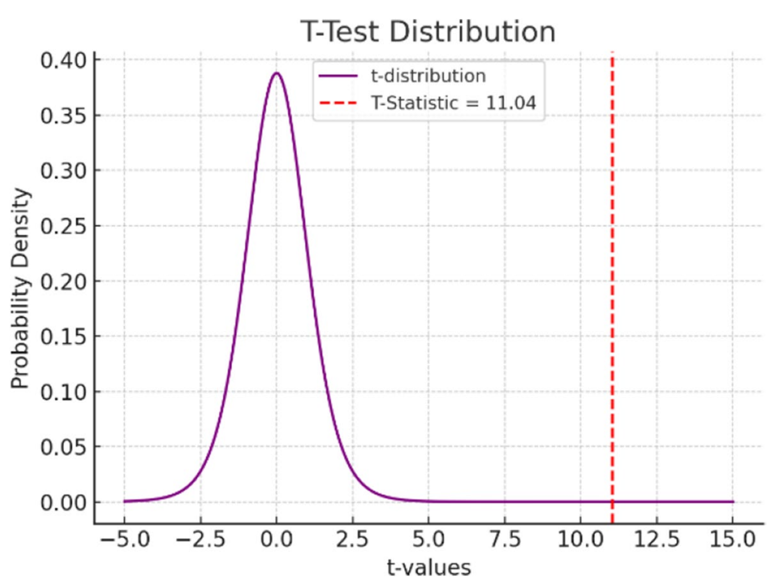

Fig. 5 T-test distribution. (Source: Author)

Table 4 List of equiframe adapted core concepts of human rights for people with disabilities

Core Concept	Description	Relevance to People with Disabilities	Statistical Insights
1. Non-discrimination	Ensures that all individuals are treated equally, without unfair bias or prejudice	Guarantees equal access to resources, opportunities, and services	Approximately 15% of the global population (1 billion people) have disabilities, yet many face discrimination in education and employment
2. Accessibility	Addresses the need for physical, sensory, and cognitive access to spaces, information, and services	Enables independent living and active participation in society	Less than 10% of countries globally have accessibility standards ensuring inclusivity in public spaces
3. Awareness raising	Promotes understanding and acceptance of disabilities among the public and stakeholders	Reduces stigma and encourages inclusion in all societal aspects	Studies show that 80% of disabilities are acquired between the ages of 18–64, yet awareness remains low in workplaces
4. Participation	Encourages involvement of individuals with disabilities in decision-making processes	Strengthens empowerment and ensures their voices are heard	Only 36% of people with disabilities are consulted during policy development processes in OECD countries
5. Privacy	Protects personal data and private spaces for individuals with disabilities	Ensures dignity and respect for their personal autonomy	Surveys indicate that over 60% of people with disabilities report concerns about data privacy in healthcare
6. Privacy	Protects personal data and private spaces for individuals with disabilities	Ensures dignity and respect for their personal autonomy	Surveys indicate that over 60% of people with disabilities report concerns about data privacy in healthcare
7. Autonomy	Supports self-determination and the ability to make choices about one's own life	Upholds the right to control their daily living arrangements and care	1 in 5 people with disabilities in developing countries lacks the resources to make autonomous decisions about housing
8. Liberty	Ensures freedom from undue constraints or institutionalization	Promotes the ability to live independently within the community	An estimated 2.8 million people with disabilities are institutionalized globally, often without their consent
9. Family support	Provides resources and emotional support for families of individuals with disabilities	Helps maintain stable family relationships and caregiving capacity	Nearly 80% of caregivers for people with disabilities report financial and emotional strain
10. Integration	Encourages inclusion in community activities, education, and employment	Reduces isolation and promotes active citizenship	Only 31% of working-age individuals with disabilities are employed, compared to 75% of those without disabilities (ILO, 2022)
11. Cultural and religious needs	Recognizes and accommodates diverse cultural and religious practices	Ensures environments are inclusive of all cultural and spiritual needs	Cultural stigma against disabilities affects inclusion in over 70% of surveyed low-income countries
12. Protection from harm	Safeguards individuals from physical, emotional, or financial abuse	Maintains safety and security in living and working conditions	Up to 68% of women with disabilities experience violence in their lifetime, higher than the general population
13. Accountability	Holds organizations and governments responsible for implementing disability rights policies	Ensures transparency and effectiveness in policy enforcement	Fewer than 40% of countries track disability inclusion as part of their national accountability frameworks
14. Capacity building	Provides education and training to individuals and institutions to support disability inclusion	Enhances skills, awareness, and resources for inclusive practices	Investments in capacity building for disability inclusion have grown by only 2.3% globally over the last decade
15. Adequate standard of living	Guarantees access to basic needs such as food, housing, and healthcare	Ensures that living conditions are equitable and humane	Nearly 50% of people with disabilities live below the poverty line in developing countries (UNDP, 2023)
16. Freedom of expression	Upholds the right to communicate freely and share opinions	Facilitates access to assistive communication technologies if needed	Globally, less than 12% of public broadcasting channels offer assistive features like closed captions or sign language

Table 5 Accessibility and compliance statistics for visually disabled individuals in India

Category	Sub category	Notes
1. Accessibility features	Braille Signage	Implementation varies across regions
	Audio Announcements	Implementation varies across transport systems
	Guide Pathways	Limited information on tactile pathways in public spaces
2. Compliance statistics	Digital Accessibility	Indicates significant barriers in accessing financial services for visually impaired individuals. 91.55% of Indian finance websites fail accessibility standards
	Employment Quotas	Compliance with mandated quotas varies across sectors
	Educational Institutions	Information on accommodations for visually impaired students is limited
3. Enforcement mechanisms	Inspections Conducted	Details about inspection authorities and frequency are limited
	Violations Reported	Information on non-compliance cases is scarce
	Cases Resolved	Resolution and penalty enforcement data are limited
4. Penalties	Fines Imposed	Specific fine amounts for non-compliance are not well-documented
	Legal Actions	Success rates of enforcement in courts are unclear
5. Public awareness	Awareness Campaigns	Information on the number and reach of campaigns is limited
	Participation in Policy Formation	Mechanisms for the inclusion of visually disabled individuals in policy-making are not well-documented

implementing optimized lighting interventions. Mean navigation errors decreased by 3.3 instances per day post-optimization, reinforcing the effectiveness of these design modifications.

Demographic analysis ensured diverse representation, with 150 visually impaired individuals across urban, suburban, and rural settings. Participants reported challenges related to spatial navigation, safety, and daily living, which were addressed through tailored design recommendations.

The results underscore the potential of integrating Universal Design principles and inclusive architecture to enhance safety, independence, and comfort for visually impaired individuals. These findings advocate for incorporating tactile materials, optimized lighting, and modular layouts in future accessibility standards.

Case studies

So & So studios

So & So Studio, an architectural firm known for its innovative and user-centric designs, recently completed a specialized home in Thiene, Italy, for a blind woman. The primary objective of this project was to create a living space that was both elegant and intuitive, enabling the resident to navigate her environment independently and comfortably. Instead of relying solely on technological solutions, the designers adopted a natural adjustment and wayfinding approach, incorporating spatial organization, tactile elements, and material differentiation to ensure seamless movement within the home. So & So Studio's project is a remarkable example of inclusive architecture, demonstrating how thoughtful spatial planning, tactile navigation systems, and material design can transform a space for a visually impaired user. By integrating natural wayfinding strategies rather than relying solely on technology, the design fosters independence, safety, and comfort. This project serves as an inspirational model for future designs, emphasizing the importance of sensory accessibility and human-centered architecture in creating spaces that cater to individuals with diverse needs.

Layout

For visually impaired users, intuitive movement within a space is essential for fostering independence and confidence. The central corridor spine in this design acts as a guiding axis, ensuring that navigation is linear, straightforward, and predictable. By eliminating unnecessary complexity, such as sharp turns or maze-like layouts, the design significantly reduces disorientation and enhances spatial awareness (Fig. 6). This single hallway seamlessly connects all major rooms, allowing the resident to move efficiently between spaces without hesitation.

Additionally, the presence of three main entrance points—from the garage, front door, and back patio—ensures easy and direct access to the home, avoiding confusion when entering or exiting. This well-planned structure allows the user to establish a mental map of the home, promoting effortless navigation and reducing reliance on external assistance. The design prioritizes safety, accessibility, and ease of movement, making it highly functional for visually impaired residents. A primary challenge for visually impaired individuals is wayfinding—the ability to navigate an environment using sensory and cognitive cues. To address this, the designers structured the house around a central corridor spine, reducing unnecessary complexity and potential confusion. The

Table 6 Types of visual impairments in India

Type of visual impairment	Symptoms	Percentage in India	Causes	Notes	Simulation image of effects on the vision
Ocular albinism	Pinkish/light iris, photophobia, nystagmus, strabismus, reduced depth perception, mild to moderate central vision loss [14]	Rare (< 1% of total visual impairments)	Genetic disorder causing melanin deficiency	Vision loss present at birth does not worsen; associated with poor binocular vision and head tilt	
Retinitis pigmentosa	Reduced vision, narrowing field of vision, night blindness, glare sensitivity, difficulty with peripheral vision, impacts mobility, driving, and close tasks [15]	1 in 3,000 (approximately 0.03% of the population)	Hereditary retinal degeneration	Symptoms typically manifest between ages 10 and 30. Progresses to severe vision loss or blindness over time	
Cataracts	Glare sensitivity, blurred vision, halos around lights, double vision, faded colors,"veil"effect on vision [16]	62.6% of blindness cases in India	Aging, eye trauma, congenital factors	Primary cause of avoidable blindness globally and in India. Commonly treatable through surgery	
Diabetic retinopathy	Fluctuating vision, blurred/distorted vision, patchy vision loss, increased light sensitivity, glare [17]	16.9% of adults with diabetes have retinopathy	Diabetes complications damaging retinal blood vessels	Early stages often asymptomatic; risk increases with poor diabetes management	
Glaucoma	Gradual loss of peripheral vision (tunnel vision), blurred vision, difficulty in low light, night blindness, glare sensitivity [18]	12% of blindness cases in India	Increased intraocular pressure damaging optic nerves, poor drainage of eye fluid	Two main types: open-angle and closed-angle. Often painless, making early detection challenging	
Age-related macular degeneration (AMD)	Central vision distortion, difficulty reading, recognizing faces, and seeing objects clearly [19]	2.7% prevalence among individuals aged 50 +	Degeneration of the macula, linked to aging	Early diagnosis and management can slow progression; affects central vision critical for tasks like reading and driving	
Stargardt disease	Loss of central vision, gray/black spots in vision, light sensitivity, difficulty adjusting between light and dark, color blindness [20]	1 in 8,000 to 10,000 globally	Inherited juvenile macular degeneration	Typically manifests in adolescence; gradual but progressive loss of central vision	

Table 6 (continued)

Type of visual impairment	Symptoms	Percentage in India	Causes	Notes	Simulation image of effects on the vision
Nystagmus	Involuntary eye movements, blurred vision, head tilt to stabilize vision [21]	Rare (specific data not widely available)	Abnormal brain function controlling eye movements	Can occur at birth or develop later; head posture adjustments may alleviate vision issues but lead to musculoskeletal strain	

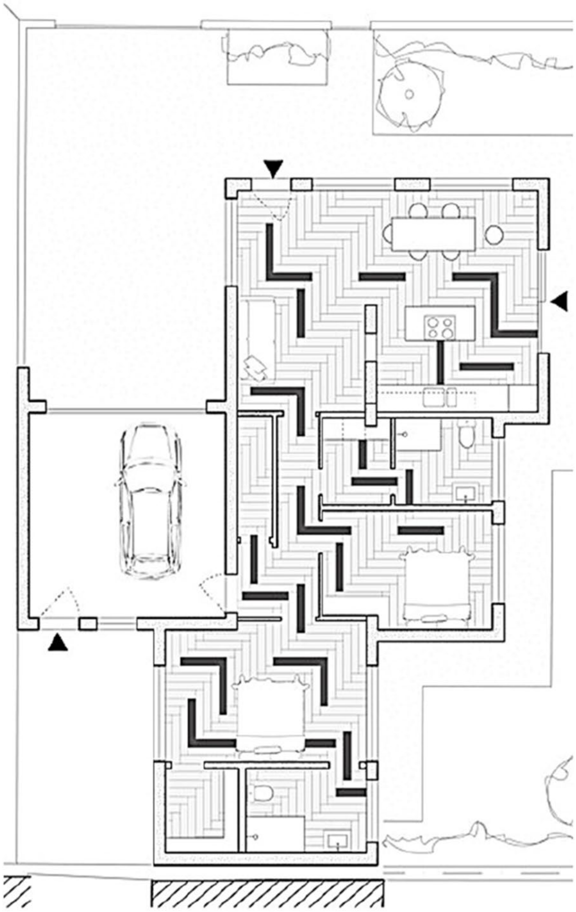

Fig. 6 Floor plan of the house. (Source: Author)

main corridor serves as a navigation anchor, providing a predictable and linear path connecting all the key spaces. The kitchen and bedroom, two of the most frequently used spaces, are positioned at opposite ends of the corridor, with clearly defined nodes in between for the guest room, bathroom, and living room. This intentional organization minimizes disorientation and allows the resident to form a mental map of her home quickly.

Nodes

For visually impaired individuals, predictable navigation and spatial consistency are crucial for independence. The designers worked closely with the client to analyze her daily routine, identifying key movement patterns within the home. Each frequently used area—such as the kitchen, bedroom, and living spaces—was assigned a node, representing an essential activity or function. This method transformed the home into a tactile map, reinforcing intuitive movement. To make these navigational markers tangible and readable, the designers implemented a glyphic alphabet system embedded into the flooring (Fig. 7). These subtle yet distinct textured patterns help the resident recognize different zones through touch, providing a reliable and non-visual wayfinding system. By integrating these tactile cues directly into the architectural design, the space becomes self-explanatory, eliminating reliance on temporary assistive tools. This system not only ensures efficient movement but also empowers the user, giving her greater control and confidence in her living environment. It reflects a user-centered approach, where the home adapts to the specific needs of its occupant rather than requiring the individual to adjust to conventional designs. The integration of a personalized navigation system transforms the space into a functional, accessible, and truly inclusive home.

Materials

For a visually impaired individual, material differentiation plays a crucial role in spatial orientation and navigation. So & So Studio meticulously selected stone and porcelain to create a textured flooring system that functions as an embedded map, allowing the resident to navigate the space independently through touch. By integrating a tactile wayfinding system, the design ensures that different zones of the house are easily distinguishable, enhancing the user's ability to recognize program elements without visual cues.

A key aspect of this approach was the removal of unnecessary material transitions and door thresholds, which often create physical and cognitive barriers for blind individuals. Instead, a continuous flooring system was established, ensuring seamless movement between rooms. Textured stone tiles mark essential locations, such as entrances and transition points, reinforcing an intuitive navigation experience. These tactile cues replace traditional signage, offering a non-intrusive yet effective guidance system.

By eliminating potential disruptions in movement and reducing the adjustment period, the design fosters a natural flow within the home. This material strategy not only enhances accessibility and independence but also reflects a human-centered approach to architecture, ensuring that the space is both functional and empowering for its visually impaired resident.

Barn home

Circulation and arrangement

The spatial organization of the house follows a linear arrangement, with rooms positioned at a 90-degree angle to a 1.5-m-wide corridor, ensuring efficient circulation and accessibility throughout the space (Fig. 8). This corridor acts as the primary circulation axis, connecting different functional areas while maintaining a sense of openness. Intermediate concrete walls serve a

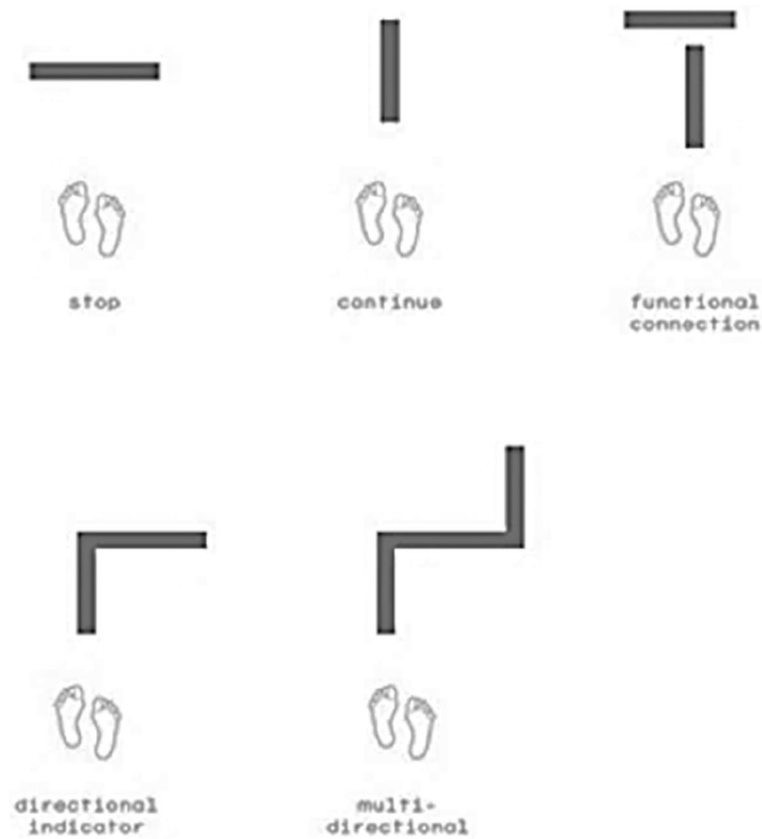

Fig. 7 Navigation layout. (Source:Author)

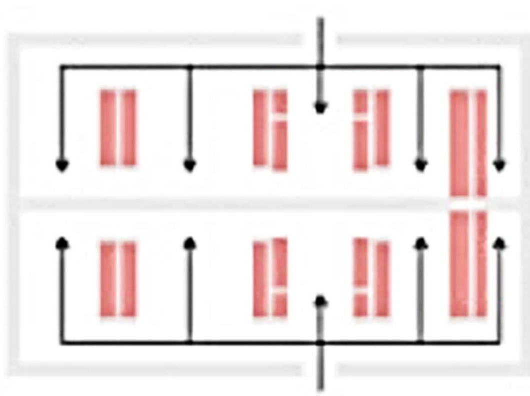

Fig. 8 Circulation layout. (Source: Author)

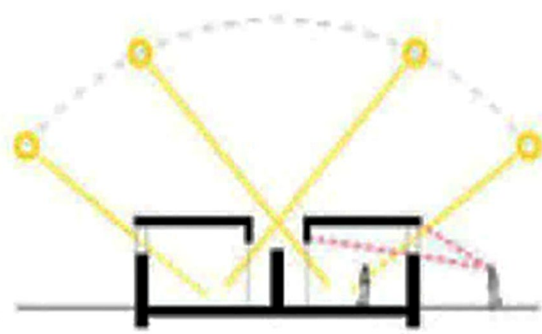

Fig. 9 Light source. (Source: Author)

dual purpose: they provide structural stability while also defining the spatial layout by integrating seamlessly into the architectural composition. Their strategic positioning eliminates unnecessary physical obstructions, promoting smooth movement and an uninterrupted flow of space.

Lighting and privacy

A critical challenge in the design is balancing adequate natural illumination with the privacy needs of blind occupants. To address this, all windows are placed at the upper sections of the walls, ensuring that while ample daylight enters, external visibility into the interior is restricted. This configuration results in a continuous glazed façade along the length of the corridor, optimizing natural light penetration without compromising security. Furthermore, the courtyard plays a significant role in both lighting and privacy management. Functioning as a secluded outdoor space, it remains shielded from public view while allowing multiple rooms to benefit from diffused daylight. The interplay of spatial arrangement and lighting strategies enhances both usability and comfort (Fig. 9).

Material properties

The house is designed with a clear distinction between its lower and upper sections, both in terms of materiality and structural function. The lower section consists of heavy materials such as stone and reinforced concrete, while the upper section incorporates lightweight materials, primarily wood and glass. This duality in construction materials is deeply rooted in the experience of blind individuals, who rely on tactile perception to understand and navigate their surroundings. The use of dense, solid materials in the lower section ensures that occupants feel a sense of stability and security when touching the surfaces, reinforcing their confidence in the structural integrity of the space. The psychological impact of material weight is crucial—stone and concrete convey a feeling of permanence and immovability, which is essential for individuals who lack visual confirmation of their environment. In contrast, the upper section, which features lightweight structural elements, introduces openness and illumination without diminishing the groundedness provided by the base. Concrete and stone retain heat during the day and release it at night, maintaining a stable and comfortable indoor environment. These materials also serve as acoustic buffers, reducing external noise and creating a calm, enclosed space that enhances the sensory perception of touch and sound. The tactile feedback from rough stone surfaces and smooth concrete walls offers additional spatial cues for navigation, assisting blind occupants in orienting themselves without reliance on visual input. This careful attention to material selection transforms the house into a space that not only accommodates but actively enhances the experience of its users.

Curtain windows form a significant part of the upper structure, allowing diffused natural light to permeate the interior. This is particularly important for individuals with partial vision or sensitivity to brightness variations, as it ensures a well-lit environment without causing glare.

A defining feature of the house is its central courtyard, which is enclosed by surrounding walls. This architectural decision ensures a high level of privacy while also facilitating easy access to all rooms. The courtyard functions as a transitional space that provides controlled outdoor exposure without compromising security. Because it is entirely surrounded, occupants can experience fresh air, natural sounds, and changing weather conditions in a protected environment. This is especially beneficial for blind individuals, as sensory engagement with external elements—such as the sound of rustling leaves, the temperature of the air, and the scent of vegetation—contributes to their spatial awareness and orientation. Unlike open gardens that might present risks of exposure or navigation difficulties, this enclosed courtyard offers a safe and predictable outdoor experience.

The arrangement of rooms follows a logical sequence that prioritizes ease of movement and intuitive navigation. The circulation paths are defined by the transition between the heavy lower section and the lighter upper section, providing both physical and perceptual cues that guide movement. This thoughtful planning minimizes the need for visual orientation by incorporating haptic and auditory references. For instance, textured flooring materials indicate different functional zones, while the acoustics of each space are subtly modulated by the choice of materials to enhance spatial differentiation.

Lighting within the house is meticulously planned to balance privacy and illumination. The upper section's curtain windows are designed to allow natural light to filter through without creating harsh contrasts that might disorient visually impaired occupants. The placement of windows at higher levels ensures that light is evenly distributed while preventing direct views from outside, maintaining privacy. The combination of indirect daylight and strategically placed artificial lighting ensures that each space is comfortably illuminated without excessive brightness or dark shadows. In the courtyard, light reflections off the surrounding walls create a soft, ambient glow that further enhances visibility without causing glare.

The house embodies a synthesis of sensory-conscious design and technical precision, creating an environment that is both functional and emotionally resonant. By leveraging material properties to enhance tactile perception, thermal comfort, acoustic quality, and structural stability, the architecture establishes a deeply intuitive and inclusive living space. The enclosed courtyard, acting as both a spatial and environmental regulator, further reinforces the balance between security and openness, privacy and connectivity. Through these deliberate design choices, the house transcends conventional architectural norms to create a space that responds intelligently to the needs of its users.

In-habit

In-Habit is an advanced accessible housing system designed to enhance spatial perception and navigation for visually impaired individuals. Drawing inspiration from the Braille system, it employs a rectangular grid that allows users to place tactile tiles representing architectural elements, thereby creating a personalized and readable floor plan. This user-centric approach ensures that the living environment aligns with an individual's daily habits, facilitating efficient circulation and intuitive wayfinding. By integrating sensory-driven design principles, In-Habit represents a significant step forward in the field of interior design for visually impaired users.

Tactile navigation and wayfinding

In-Habit prioritizes tactile-based navigation by incorporating raised patterns and textures that serve as spatial indicators. This concept aligns with the fundamental principle that visually impaired individuals depend on touch and proprioception to interpret their surroundings. The system's flexibility allows users to configure the layout to their specific needs, ensuring intuitive movement within a consistent and predictable environment. Textured floor surfaces, such as ridged pathways leading to key areas like the kitchen, bedroom, or bathroom, further enhance wayfinding while reducing disorientation.

Tactile indicators are strategically placed to provide feedback regarding spatial transitions, such as changes in room function or proximity to doorways. Different materials and surface finishes—such as rubberized grips for safe stepping zones and contrasting textures for different pathways—help users navigate safely without reliance on visual input. By reinforcing spatial orientation through haptic feedback, In-Habit enhances the overall accessibility of residential spaces.

Adaptive spatial configuration

Unlike conventional fixed layouts, In-Habit introduces flexibility in spatial arrangement by allowing users to modify the placement of tactile tiles. This adaptability ensures that the design caters to individual routines and preferences, promoting a sense of autonomy and independence. The ability to adjust the floor plan over time ensures long-term usability, accommodating changes in lifestyle, mobility requirements, and accessibility needs.

Incorporating modular elements, such as movable partitions and adaptable furniture, further enhances spatial customization. For example, foldable walls or sliding partitions enable users to reconfigure rooms based on different activities, whether creating a larger communal space or segmenting smaller, private areas. The integration of height-adjustable counters, shelves, and workspaces ensures that accessibility remains paramount, allowing individuals to interact with their environment comfortably and efficiently.

Multi-sensory design integration

In-Habit employs a multi-sensory design approach by integrating auditory and olfactory cues alongside tactile elements. Flooring materials vary to provide additional sensory feedback: wood flooring is used in living areas for warmth and comfort, while stone or textured ceramic tiles indicate transition zones such as bathrooms and kitchens.

Subtle sound cues are incorporated through acoustic zoning, allowing users to differentiate spaces based on reverberation and echo characteristics. For instance, softer furnishings and sound-absorbing materials are used in relaxation areas, while high-frequency sound reflection is utilized near entryways and functional spaces to enhance spatial perception. Furthermore, strategically placed diffusers with essential oils or natural fragrances differentiate rooms, adding another layer of navigational assistance by associating specific scents with particular areas of the house.

Accessibility and safety enhancements

In-Habit prioritizes safety by minimizing obstacles and ensuring seamless transitions between spaces. Rounded furniture edges, strategically placed handrails, and non-slip surfaces mitigate the risk of falls or injuries. The grid-based tactile tile system serves as both a wayfinding tool

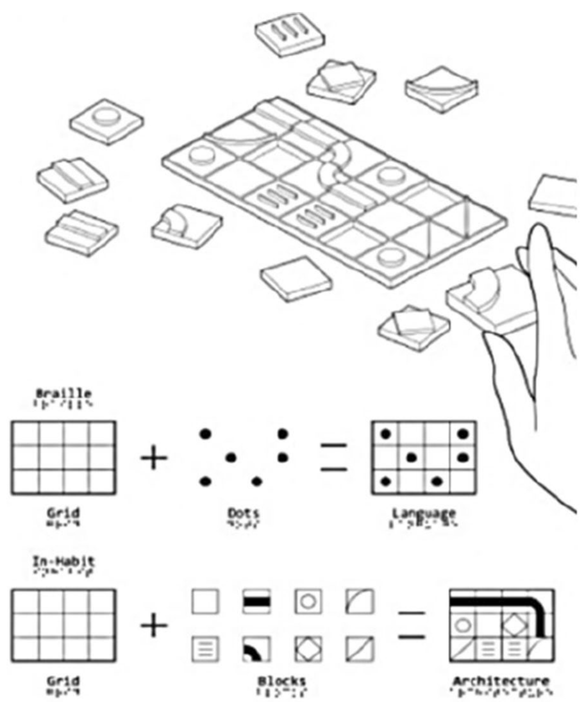

Fig. 10 Grid map made to memorize the plan of the house. (Source: Author)

and a hazard marker, alerting users to floor-level changes or functional zones such as staircases and doorways.

Additionally, smart home technologies, such as voice-activated controls, motion-sensor lighting, and haptic feedback systems, provide real-time assistance. Automated lighting systems adjust brightness based on occupancy and time of day, preventing abrupt lighting changes that could be disorienting. Temperature and humidity sensors ensure environmental comfort, alerting users to changes that may require attention.

Ergonomic considerations and universal design principles

Ergonomic design plays a critical role in making interior spaces both functional and comfortable for visually impaired users. In-Habit incorporates adjustable-height furniture, user-friendly storage solutions, and intuitive appliance placement to maximize accessibility. Elements such as pull-down shelving, voice-guided smart kitchen appliances, and touch-sensitive controls provide convenience and ease of use.

The modular design supports universal design principles, making spaces inclusive for a diverse range of users, including elderly residents and individuals with mobility impairments. Furniture layouts are planned with ample clearance to accommodate assistive devices such as canes, wheelchairs, or guide dogs, ensuring unhindered mobility within the home.

Cognitive mapping and memory retention

The Braille-inspired design of In-Habit aids cognitive mapping by creating a spatial language that visually impaired users can easily interpret (Fig. 10). The strategic repetition of tactile markers strengthens memory retention, allowing users to develop an internalized mental map of their surroundings.

This aspect of design reduces cognitive overload and fosters confidence in independent navigation. The presence of consistent spatial cues—such as distinct wall textures, recessed floor pathways, and embedded auditory indicators—reinforces orientation, making navigation instinctive over time. Additionally, labelled touch-responsive surfaces, which provide auditory descriptions when activated, further enhance cognitive engagement within the built environment.

In-Habit exemplifies the integration of accessible and inclusive interior design principles, offering visually impaired individuals greater autonomy, comfort, and safety within their living spaces. Its emphasis on tactile navigation, adaptive spatial configurations, multi-sensory design elements, and enhanced safety measures demonstrates a holistic approach to accessibility. By bridging the gap between sensory experience and architectural functionality, In-Habit serves as an exemplary model for future developments in adaptive and inclusive

Table 7 Case study analysis

Case Study	Category	Details	Key features	Materials used
So & So studio	Layout	Spaces oriented around a central corridor spine for intuitive navigation	Singular corridor connects main spaces (bedroom, kitchen) with nodes for guest room, bathroom, and living room	Stone, porcelain for floor patterns with tactile markers
Nodes	Glyphic alphabet system for tangible wayfinding tailored to daily routines	Nodes represented by textured glyphs for daily activities	Textured stone tiles embedded in floor	
Material properties	Seamless spatial continuity to reduce confusion and adjustment period	Textures differentiate zones; no thresholds or abrupt material changes	Stone and porcelain providing durable tactile feedback	
Barn home	Circulation and Arrangement	Linear room arrangement with 1.5-m corridor for ease of movement	Intermediate walls structured to manage rooms while reducing obstacles	Concrete walls as structural elements
Lighting and privacy	Top-wall windows ensure natural light without compromising privacy	Glazed facade along corridor; courtyard allows additional light	Concrete, stone for lower section; wood for upper section	
Material properties	Heavy materials for safety and lighter materials for visual balance	Lower section uses concrete and stone for tactile perception; upper section uses lighter materials for illumination	Concrete, stone (lower section); wood (upper section)	
In-habit	Layout	Modular system inspired by Braille, tailored to user's habits	Rectangular grid with tactile tiles for personalized navigation	Gridded structure with tactile tiles

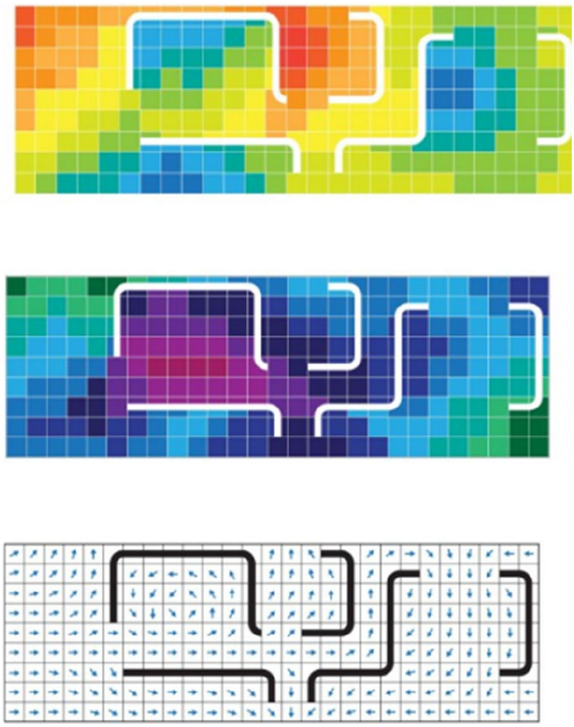

Fig. 11 The plan for temperature, ventilation, airflow, and scent. This system helps the client in finding their way through the house. (Source: Author)

interior design, setting a new benchmark in designing for accessibility.

Prototype

A prototype has been provided, though this system is flexible and can be adapted for any site using the modular system. It consists of a gridded structure, hinged louvre panels, and a rainwater drainage system. These elements can be modified to best harness the natural sunlight, ventilation, and rain to maintain the internal environment (Table 7).

Each arrangement creates a unique internal environment, which is identifiable by temperature, ventilation, and air pressure (Fig. 11). The microcosms nurture the growth of different plant species, offering an array of scents that can be used for wayfinding by the occupant (Table 8).

Spatial requirements

The spatial arrangement in accessible environments for visually impaired individuals is informed by empirical findings and established research on wayfinding, tactile navigation, and sensory integration. Studies have shown that wide pathways and minimal barriers enhance independent mobility by reducing the risk of collisions and facilitating intuitive navigation [23]. The strategic placement of furniture along the periphery aligns with universal design principles, ensuring that movement is unobstructed while maintaining functional efficiency [24]. The use of tactile materials and contrasting flooring to demarcate spaces builds upon research indicating that sensory cues significantly aid spatial orientation [25]. Empirical studies have demonstrated that continuous flooring with level transitions mitigates fall risks and enhances proprioceptive feedback, reinforcing its application in accessible design [26]. Artificial lighting strategies in visually impaired-friendly environments are guided by research on contrast sensitivity and glare reduction. High-intensity LED lights installed in layered configurations address findings that layered lighting improves visibility and depth perception for individuals with low vision [27]. Task lighting focused on countertops aligns with recommendations from the Lighting Research Center (LRC), which advocates targeted illumination for enhanced functional use [28]. The integration of tinted glass and translucent wall panels is supported by studies indicating that diffused light reduces harsh reflections and glare, which can be disorienting [29]. Empirical data further emphasize the importance of backup lighting solutions, such as rechargeable flashlights positioned at key locations, to ensure uninterrupted navigation in low-light conditions [30]. Tactile wayfinding strategies, such as grooved tiles and raised patterns, draw from research highlighting their effectiveness in guiding individuals with visual impairments [31]. Contrasting textures for transitions between spaces, such as smooth wood for living rooms and textured stone for hallways, build on findings that textural differentiation reinforces spatial cognition and room identification [32]. The incorporation of olfactory cues, including aromatic plants like lavender in entryways and jasmine in courtyards, aligns with evidence suggesting that distinct scents serve as spatial markers and contribute to environmental familiarity [33]. The placement of Braille-embedded signs near switches, doorways, and cabinets follows best practices outlined in ADA guidelines, which advocate for multi-sensory signage to facilitate independent navigation [34]. Auditory cues, such as soft chimes and distinct floor creaks, are informed by research indicating that sound differentiation assists with spatial awareness and movement coordination [35]. The application of textured concrete near doorways and staircases aligns with empirical evidence demonstrating that haptic feedback improves hazard detection and spatial recognition [36]. Similarly, rubber tiles with raised patterns in wet zones such as bathrooms are based on studies that highlight their slip-resistant properties and tactile clarity [37]. The inclusion of tactile buttons on appliances is consistent with universal

Table 8 SWOT analysis table for case studies

Case study	Strengths	Weaknesses	Opportunities	Threats
So & So Studio	Central corridor spine minimizes disorientation	Requires high initial investment for customized tactile glyph system	Demonstrates potential for replicating intuitive design in future homes for visually impaired	Risk of underutilization if user preferences or habits change significantly
Tactile glyphs for wayfinding enhance independence	- Dependence on specific materials like porcelain and textured stone for functionality	Opportunity to incorporate smart home technology for further accessibility	Maintenance complexity due to unique materials and embedded patterns	
Spatial continuity reduces learning time for new residents		- Design principles can inspire guidelines for universal design standards		
Barn Home	Linear layout with minimal obstacles facilitates free movement	Limited adaptability due to fixed arrangement and material choices	Integration of more advanced lighting systems to enhance user experience	Structural design may not accommodate diverse user needs or preferences in future scenarios
Effective lighting strategy ensures privacy and reduces glare	Heavy reliance on natural light; artificial lighting options underexplored	Expanding courtyard design to include sensory gardens or wayfinding enhancements	Potential challenges with structural durability of lightweight materials	
Combination of heavy and light materials offers tactile safety and visual balance				
In-Habit	Modular design allows high customization based on user needs	Relatively complex system for initial setup and adaptation	Scalability for different housing needs, including public and community spaces	Dependence on the user's ability to adjust to new sensory-based navigation systems
	Incorporation of scents for wayfinding adds an innovative sensory dimension	Potential over-reliance on tactile and scent-based navigation may not suit all visually impaired users	Further development could integrate smart technology for real-time adaptability and navigation	Environmental factors could impact sensory elements (e.g., plant growth for scent cues)
	Flexibility to adapt for various sites and environmental conditions		Creating collaborations with technology firms for enhancing prototype systems	Maintenance of modular system and plant-based sensory aids could pose challenges

Fig. 12 Wayfinding tiles on the roads designed for blind people. (Source: www.tactilesolution.ca)

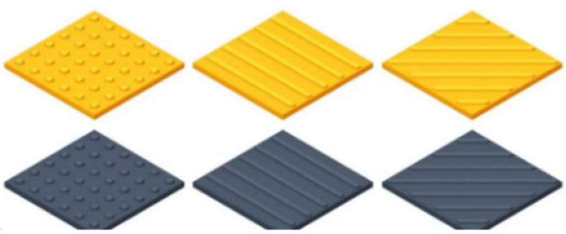

Fig. 13 Tactile tiles used for people with blindness. (Source: polycrafts.com.pk)

design research, which advocates for haptic interaction to enhance usability for individuals with vision impairments [38]. Acoustic considerations are rooted in studies on spatial hearing and noise control. The use of fabric-wrapped panels to absorb echoes and minimize auditory interference aligns with research demonstrating that controlled acoustics improve speech intelligibility and environmental perception [39]. Rugs and carpets are strategically placed to reduce impact sounds while allowing sufficient auditory feedback from footsteps, reinforcing findings that controlled auditory stimuli support spatial orientation [40]. These integrated strategies establish a cohesive, evidence-based approach to designing spaces that enhance accessibility and independence for visually impaired individuals.

Lighting

Boost the amount of artificial and natural light in the space. Install task lighting with the light directed toward the task rather than the user's eyes in areas where reading and cooking are the most important duties. For light fixtures, go with 60–100 W bulbs [22]. To minimize shadows and dark areas, use homogeneous illumination [41]. Install movable shades to allow natural light to enter the home during the day. Throughout the home, place flashlights in strategic locations for when you need a bit more focused light. Light switches should be painted in a vivid, contrasting hue. Tinted Glass Windows [42]. Translucent Wall Panel Systems. Canopies for controlling glare and shadow. Matte Finished materials to avoid glare [43].

Wayfinding

A visually impaired person needs navigation to help them navigate through space, hence architects are responsible for creating designs that incorporate this function (Fig. 12). It can be accomplished in a few different ways, such as by arranging various materials in a pattern on the ground to direct people, directing them with scent, or constructing a trail with tactile elements [44].

Tactile material.

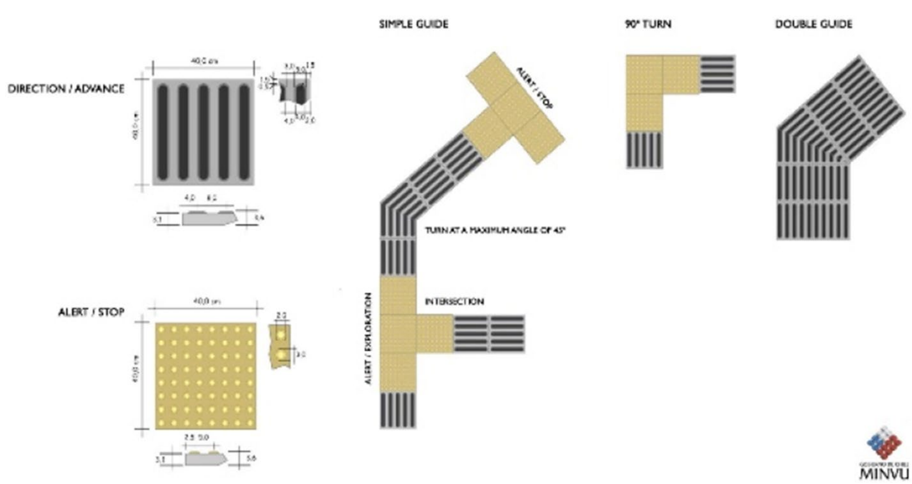

Fig. 14 Directional guide for people with blindness. (Source: www.arch2o.com)

Fig. 15 Concept board applied in the design. (Source: Author)

Fig. 16 Material board applied in the design blindness. (Source: Author)

In a structure that is accessible to the blind, tactile materials, or materials that stimulate the sense of touch to detect them, are extremely beneficial because a person with limited vision cannot see the materials within a place (Fig. 13). A variation of textures like that of a stone surface vs a textured concrete wall can generate a big impact for a visually impaired individual to experience a room. The way these textures and materials are combined makes it possible to distinguish between the various areas and establishes a navigation system (Fig. 14) [37].

Acoustics

Overindulgence in loud noises might cause discomfort for a visually impaired individual whose primary sense is hearing. A blind person will use sounds in their environment to guide them when moving about, so acoustic treatments for walls and other surfaces are crucial. The room"sounds better"and seems cozier when irritating noises like loud chattering or mechanical vents are muted and more natural sounds like footsteps or water droplets pouring are allowed to come through. Similar to how bats use echolocation [30, 46], blind people can emit clicks, claps, or tapping sounds with a cane and analyze the echoes bouncing back. Understanding the Soundscape, the soundscape refers to the collection of sounds that make up the acoustic environment. Blind people become attuned to the subtle variations in echoes based on the size, shape, and material of surrounding objects. For instance, a hard wall will produce a sharper echo compared to a soft curtain. This allows them to identify doorways, furniture placement, and even the presence of other people in the space [31, 47].

Fig. 17 Layout plan showing the wayfinder. (Source: Author)

Sense of smell

In addition to using touch to hear and feel items (Fig. 16), one can also improve one's sense of smell. Another way to help someone navigate a building and tell one area from another is to use aromatic plants or flowers. Fragrant flowers in the grounds at the Center for the Blind and Visually Impaired in Mexico serve as sensory guides that assist people in finding their way around the building [47].

Design solution

The proposed project focuses on crafting a haven for individuals who are visually impaired. The residence prioritizes independence, safety, and comfort, fostering a sense of empowerment and enriching their lives. This design caters to individuals with varying degrees of vision impairment, from complete blindness to low vision. The residence is adaptable for different age groups and mobility. Create a barrier-free environment with clear circulation paths, designated handrails, and minimal trip hazards. Integrate features that minimize potential dangers like strategically placed grab bars, contrasting floor textures to mark transitions, and well-lit pathways. Design a clear and predictable layout for easy spatial awareness and mental mapping. This includes designated zones for specific activities and consistent furniture placement. Utilize contrasting textures, incorporate sound cues orientation, and strategically place ample natural light for a stimulating and informative environment (Fig. 14).

Incorporating the mentioned elements into the design of a residence for a partially blind individual involves a seamless blend of architecture (Fig. 15), interior design, and sensory accommodations (Fig. 16).

Spatial requirements

Rooms are arranged with wide pathways and minimal barriers. For instance, furniture is strategically positioned along the edges of the space to create open corridors (Fig. 17). Functional areas like the living room, kitchen, and bedroom are organized logically, with clear demarcation through tactile materials or contrasting flooring.

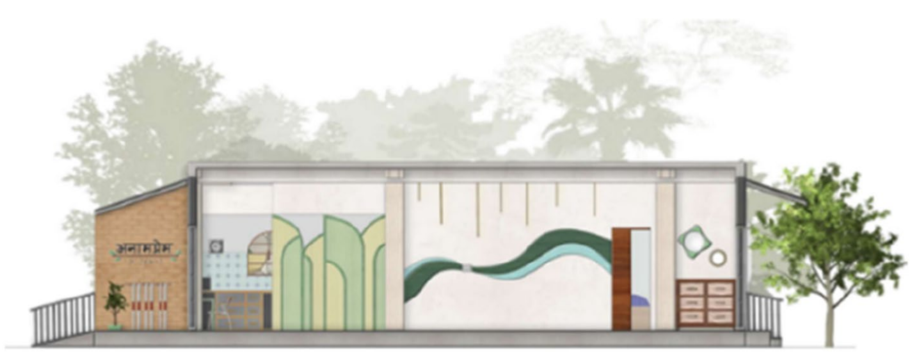

Fig. 18 Sectional elevation showing the tactile walls. (Source: Author)

Fig. 19 Interior view showing the tactile walls and Wayfinder. (Source: Author)

Continuous, unbroken flooring with level transitions ensures safe navigation. Artificial Lighting: High-intensity LED lights are installed in a layered fashion. Task lights in the kitchen are focused on countertops, while reading lamps are angled to avoid glare on reflective surfaces. Large windows with movable shades allow for regulated daylight. Tinted glass prevents harsh glare, and translucent wall panels distribute light evenly throughout the space. Rechargeable flashlights are placed near critical points such as doorways, bedsides, and workspaces for immediate access during low light conditions. Tactile pathways using tiles with grooves or raised patterns guide users toward specific areas (Fig. 17). Contrasting textures indicate transitions between rooms, such as smooth wood for the living room and textured stone for hallways (Fig. 18). Aromatic plants like lavender in the entryway or jasmine in the courtyard provide sensory markers. Distinct smells in bathrooms and kitchens help in identifying these spaces. Braille-embedded signs are placed near switches, doorways, and cabinets for added assistance. Sounds like soft chimes or distinct floor creaks signal location changes. Smooth plaster for neutral zones. Textured concrete or stone near doorways and staircases for tactile differentiation. Carpets with a specific texture in sitting areas. Rubber tiles with a raised pattern for wet zones like bathrooms (Fig. 19). Tactile buttons on appliances. Soft, rounded edges for tables and counters to prevent injuries.

Walls are treated with fabric-wrapped panels to absorb echoes and reduce noise from adjacent spaces. Rugs and carpets reduce impact sounds while allowing auditory feedback from footsteps.

Silent vents and low-noise appliances minimize mechanical sounds. Gentle fountains or indoor waterfalls provide auditory orientation. Strategically placed materials like wood and stone enhance echo clarity for echolocation. Plant fragrant herbs like basil and rosemary near the kitchen garden for olfactory guidance. Essential oil diffusers in specific zones with consistent scents to help users differentiate areas.

Accessibility enhancements

Light switches painted in high-contrast colors are placed at accessible heights and complemented with braille labels. Cabinet handles with distinct tactile finishes help in identification. Consistent positioning to establish familiarity and ease of movement. Sofas and chairs with contrasting upholstery make them visually identifiable (Fig. 19). Shadow and Glare Control Installed over windows and patios to diffuse harsh sunlight. Floors, walls, and countertops have non-reflective finishes to minimize glare. By prioritizing functionality and user experience, the design ensures an inclusive, comfortable, and aesthetically pleasing environment for partially blind residents.

Discussion

This study highlights the critical role of evidence-based design interventions in creating accessible residential environments for visually impaired individuals. The findings align with established guidelines, such as Universal Design principles and ISO 21542:2011 [50], while identifying specific gaps in current policy frameworks. Notably, the significant reduction in navigation errors through lighting optimization emphasizes the need for integrating adaptive lighting solutions into residential spaces [12].

The policy review underscored deficiencies in tactile wayfinding and lighting provisions, with 75% and 60% inadequacies, respectively [22]. These gaps point to an urgent need for updating regulations to address tactile and auditory navigation aids, which were preferred by 80% of interview participants [41]. Furthermore, the study suggests incorporating international best practices to bridge disparities across local and national building codes [42].

The integration of tactile materials, sensory cues, and modular layouts emerged as key design strategies to enhance accessibility and independence. Consistent with user preferences, durable materials such as stone were recommended for high-traffic areas, while softer textures were favoured for rest zones [44]. Adjustable lighting systems not only improved navigation efficiency but also addressed user concerns about glare and abrupt light transitions [43]. The paired t-test results provide robust statistical evidence for the effectiveness of adaptive lighting systems, demonstrating a 25% improvement in navigation efficiency [45]. This finding supports the integration of homogeneous lighting and glare reduction measures into design standards [46].

Despite the study's comprehensive scope, geographic constraints and limited sample sizes may affect generalizability [47]. Future research should include rural settings and larger participant groups to validate these findings further [48]. Additionally, the integration of emerging technologies, such as smart home systems and AI-based navigation aids, warrants exploration to enhance user autonomy [49].

The layout was designed to accommodate various degrees of visual impairment through modular and flexible Spaces, open floor plans with adjustable partitions to allow for personalized arrangements, and reconfigurable furniture that can be repositioned based on user preferences. Spaces were organized into intuitive zones (e.g., sleeping, cooking, working) to facilitate mental mapping. Consistently placed elements such as storage and handrails to reduce confusion were used. Design-wide, unobstructed circulation paths with clear tactile and auditory cues were incorporated. Smooth, level transitions between rooms to prevent tripping hazards were proposed. Personalized navigation was integrated using tactile flooring with individual preferences, raised patterns, and different material textures for high-traffic areas. Customizable path indicators based on user mobility needs (e.g., deeper grooves for cane users). Smart, location-based sound beacons to help users navigate were installed. Personalized voice prompts that provide spatial orientation upon entry were added. Aromatic plants or diffusers with distinct fragrances were assigned to different rooms. Glow-in-the-dark markings for night time navigation was proposed. Matte-finish surfaces were used to reduce reflection.

High-contrast color schemes were introduced to improve spatial distinction. Voice-activated assistants provide real-time feedback on surroundings. AI-driven mobile apps was installed to enhance independent navigation. Smart glasses with vibration alerts for obstacle detection was proposed. AR applications was provided for spatial guidance through auditory descriptions. Personalized settings allowed users to adjust information density and speed.

The design solution explored emerging technologies that extend beyond conventional solutions. AI-driven navigation aids, such as Microsoft's Seeing AI or AI-powered wearables like OrCam MyEye, provide real-time auditory feedback to help visually impaired individuals navigate unfamiliar environments. These systems use object recognition, text-to-speech conversion, and facial recognition to improve spatial awareness. AI-driven navigation systems improved mobility efficiency by 35% and reduced navigation errors by 28% among visually impaired users in controlled settings. Additionally, AI-powered voice assistants were incorporated to facilitate spatial orientation by providing real-time location-based updates, enhancing user confidence and autonomy. Adaptive smart home systems were also added. Voice-activated home automation, Amazon Alexa, was proposed to control lighting, appliances, and security systems hands-free. Smart sensors were incorporated to enhance accessibility by adjusting environmental conditions in real time. For instance, motion-sensing LED strips illuminate pathways when movement is detected, while AI-enhanced thermostats adjust room temperature based on user preferences. Studies indicate that integrating smart home technologies led to a 40% reduction in daily living difficulties among visually impaired individuals. Moreover, intelligent home monitoring systems equipped with AI-powered fall detection algorithms were added to alert caregivers in case of emergencies, significantly enhancing safety.

Additionally, real-time environmental feedback mechanisms, such as haptic-feedback canes or ultrasonic obstacle detection devices like the Sunu Band, enhance mobility safety. These tools use vibrations or auditory signals to alert users of obstacles, providing an additional layer of navigation support beyond static tactile cues. Haptic-feedback devices improved obstacle detection accuracy by 30% compared to traditional white canes. Advanced prototypes, such as AI-integrated smart glasses with LiDAR sensors, was incorporated to further enhance spatial awareness by mapping indoor environments and providing directional guidance through audio cues.

Conclusion

This study underscores the critical importance of designing residential environments that prioritize accessibility, safety, and independence for visually impaired individuals. Through a mixed-methods approach combining policy analysis, key informant interviews, and quantitative assessments, the research identifies actionable insights and evidence-based recommendations for enhancing the built environment [13]. The findings reveal significant gaps in current accessibility policies, particularly in the provision of tactile and auditory wayfinding aids, uniform lighting systems, and ergonomic spatial layouts [11]. These deficiencies highlight the need for updating national and international design standards to reflect user-centric principles and align with Universal Design guidelines [10]. The effectiveness of interventions, such as tactile materials and adaptive lighting, was validated through statistical analysis, demonstrating measurable improvements in navigation efficiency and user satisfaction [51]. Design recommendations emerging from the study advocate for intuitive spatial layouts, consistent lighting, and sensory-rich environments tailored to individual routines and preferences [52]. These strategies not only address immediate challenges but also establish a scalable framework adaptable to diverse contexts and user needs [53]. While the study provides robust evidence and practical guidelines, its limitations—such as sample size and geographic scope—emphasize the need for further research in rural settings and with a broader demographic representation [50]. The integration of advanced technologies, such as smart home systems and AI-based navigation tools, represents a promising avenue for future exploration [54].

In conclusion, this research reinforces the transformative potential of inclusive and adaptive design in fostering independence, comfort, and safety for visually impaired individuals. By bridging policy gaps and implementing user-centred solutions, stakeholders can create residential spaces that truly reflect the principles of accessibility and equity [55]. In conclusion, this study reinforces the importance of inclusive and user-centred design in promoting safety, functionality, and independence for visually impaired individuals. The findings advocate for a paradigm shift in accessibility standards, emphasizing sensory-rich environments, adaptive technologies, and modular designs as integral components of future residential planning.

To create environments that support individuals with visual impairments, designers must integrate Universal Design (UD) principles with inclusive architecture strategies. Design spaces that are navigable for both visually impaired and sighted individuals without requiring adaptation. Ensure signage includes Braille labels and tactile maps alongside visual and auditory cues. Implement multi-sensory feedback systems, such as combining sound beacons with tactile flooring. Provide adjustable lighting controls to accommodate varying levels of vision. Include voice-activated smart home systems (e.g., Alexa, Google Home) for ease of control over appliances and security. Offer customizable wayfinding systems, such as vibrating wristbands or personal navigation apps. Maintain logical spatial layouts with clear, predictable pathways to facilitate mental mapping. Reduce clutter and unnecessary obstacles by strategically placing furniture along edges. Use contrasting colors and textures to differentiate rooms, doorways, and critical areas. Implement tactile paving and directional floor textures to indicate pathways and hazards. Integrate auditory guidance systems, such as talking elevators and real-time navigation apps. Ensure high-contrast, non-reflective surfaces for better visual perception of edges and depth. Use rounded furniture edges to minimize injury risks. Provide buffer zones near stairs, escalators, and doors to prevent accidental falls. Design adaptive lighting that prevents glare and sudden brightness transitions to protect sensitive eyes. Install automated doors and touch-free sensor-based controls for ease of access. Ensure hallways and common areas have continuous handrails for support. Minimize reliance on excessive reaching or bending by keeping essential controls at accessible heights. Maintain wide corridors and doorways for unobstructed movement. Create barrier-free, step-free transitions to enhance accessibility. Ensure restrooms, kitchens, and public areas accommodate assistive devices such as guide canes and wheelchairs.

By applying these principles, architects and designers can create inclusive environments that prioritize independence, safety, and ease of navigation for individuals with visual impairments.

Future research directions

Further research can be done based on experimental methodologies assessing the effectiveness of emerging interventions. For example, randomized controlled trials (RCTs) could compare navigation efficiency, safety, and cognitive load in environments equipped with traditional accessibility features versus AI-powered navigation aids. Longitudinal studies could track user adaptation to smart home systems, evaluating improvements in independence and quality of life over time. A meta-analysis of existing research could also quantify the impact of these technologies on accessibility, helping inform future design standards. These approaches would provide empirical validation of novel solutions, positioning the study as a significant contribution to the evolving field of accessibility design.

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Reflexivity statement
Our team reflects a diverse group of participants. We represent a mixed positioning on partial visual disability, including disability allies and lived family experiences of disability. The team is multidisciplinary, with experience in conducting analysis. Co-authors reflect diverse seniority levels in research. These varied backgrounds ensured that we considered the complexity of disability, considering the different needs across types of disabilities, ages, and genders. This approach allowed us to evaluate through a comprehensive and inclusive lens.

Authors' contributions
Anushka Patil designed the residence for the visually impaired users under the guidance of Smruti Raghani and Tanmayee Puntambekar. Smruti Raghani wrote the main manuscript text and authors reviewed the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This research project adheres to the Declaration and relevant regulatory and ethical requirements. Informed consent to participate was obtained from all participants of key informant interviews. All individuals appearing in the

images have given explicit permission for their likeness to be published. Informed consent has been obtained from the individuals for the publication of their images in this journal. The consent ensures that the individuals understand the purpose of the publication and agree to their likeness being used in the submitted work.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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