



Designing An Adaptive Age-Friendly Residential Bathroom: An Integrated Framework for Safety, Emergency Response and Sensory Comfort

¹Prof. Ms. Sucheta Nigam, ²Monesh Jain

¹Associate Professor, ²Bachelor of Design (VII Semester)

^{1/2}Dept. of Interior Design, Sanjeev Agrawal Global Educational [SAGE] University, Bhopal

ABSTRACT

Ageing can bring changes in mobility, balance, strength, vision and response time, making everyday activities within residential bathrooms increasingly challenging. Bathrooms are particularly important spaces to consider because wet surfaces, confined circulation areas and the need to transfer between standing and seated positions can increase the risk of accidents. Conventional age-friendly bathroom design generally focuses on physical accessibility and fall prevention. However, an effective residential environment should also support independent use, emergency assistance and psychological comfort.

This research paper develops an integrated design framework for an adaptive age-friendly residential bathroom, based on the dissertation study *Interior Design for Senior Citizens and Age-Friendly Spaces*. The proposed framework is organised around four principles: SAFE, INDEPENDENT, RESPONSIVE and WELLNESS. It examines the integration of conventional safety measures with three proposed design interventions: magnetic-assisted flooring with dedicated magnetic bathroom slippers, a smart emergency response system and optional acoustic wellness features.

The research uses a design-led approach supported by literature review, exploratory survey observations and site-specific spatial planning. The proposed design is developed for an existing residential bathroom measuring approximately 10 feet 6 inches by 6 feet. AutoCAD, SketchUp and D5 Render are used for spatial planning, three-dimensional development and visualisation. The magnetic-assisted flooring and smart response features are presented as design proposals requiring further technical testing, rather than as validated products.

The paper proposes that age-friendly bathroom design should move beyond the prevention of physical accidents towards an integrated environment that supports safety, independence, timely assistance and user comfort.

Keywords: Age-friendly design, senior citizens, accessible bathroom, universal design, magnetic-assisted flooring, emergency response system, acoustic wellness, residential interior design.

I. INTRODUCTION

1.1 Background of the Study

Ageing is a natural process that may involve changes in physical strength, balance, flexibility, coordination, vision and hearing. These changes can influence the way older adults interact with their everyday surroundings. Spaces that were previously easy to use may gradually

become difficult or unsafe when they are not designed to accommodate changing physical abilities.

The residential bathroom is one of the spaces where these challenges can become particularly significant. Activities such as bathing, using the toilet, washing hands and moving between wet and dry areas involve different physical movements. Wet floors, inadequate support, unsuitable fixture heights and restricted circulation can increase the difficulty of these activities.

For senior citizens, bathroom design should therefore address more than appearance and functional arrangement. It should consider how a person enters the space, moves between fixtures, maintains balance, sits and stands, and accesses assistance during an emergency.

1.2 Need for Age-Friendly Bathroom Design

A conventional bathroom is often designed around the requirements of an average adult user. However, older adults may require additional support to perform routine activities comfortably and independently. A design that does not consider these requirements may increase dependence on caregivers and reduce confidence in using the bathroom.

Age-friendly bathroom design can respond to these challenges through slip-resistant flooring, appropriate circulation, grab bars, accessible fittings, suitable lighting, seating and easily reachable emergency controls. These features can help reduce environmental barriers and support safer everyday use.

However, physical safety alone does not address every aspect of the user's experience. Older adults may also require reassurance that assistance can be accessed when needed. Comfort, privacy, ease of operation and the sensory quality of the environment are also important considerations.

1.3 Research Problem

Many age-friendly bathroom solutions focus primarily on accessibility and fall prevention. Although these measures are essential, they may not fully address emergency communication, user confidence and psychological comfort.

This creates a need for an integrated approach in which the bathroom is designed not only as a functional space but also as an environment capable of supporting the changing requirements of its users.

The central research question of this study is:

How can an age-friendly bathroom become an adaptive environment that not only prevents falls, but also responds to emergencies and supports psychological comfort?

II. AIM, OBJECTIVES AND RESEARCH METHODOLOGY

2.1 Aim of the Study

The aim of this research is to develop an adaptive age-friendly residential bathroom that integrates physical safety, independent movement, smart emergency assistance and acoustic wellness to improve the overall user experience of senior citizens.



2.2 Objectives of the Study

The major objectives are:

1. To understand the difficulties faced by senior citizens while using conventional residential bathrooms.
2. To identify important age-friendly design requirements through literature review and exploratory survey observations.
3. To develop a functional bathroom layout that supports safe movement and independent use.
4. To explore magnetic-assisted flooring with dedicated bathroom slippers as a supplementary mobility-support concept.
5. To propose a smart emergency response system that allows users to request assistance through accessible controls.
6. To incorporate optional acoustic wellness features to support comfort and relaxation.
7. To develop a site-specific design proposal using interior design drawings and three-dimensional visualisation.

2.3 Research Methodology

The study follows a design-led research approach combining secondary research, exploratory primary research and design development.

A. Literature Review

Relevant literature on geriatric bathroom design, fall prevention, accessible residential environments and age-friendly housing was reviewed to identify common design challenges and possible design responses.

B. Exploratory Survey

A questionnaire was used to gather observations about bathroom-related difficulties, safety concerns and preferences for proposed design interventions. The responses indicated concerns relating to slippery floors, balance, sitting and standing from the toilet, and access to emergency assistance.

The survey also explored the perceived usefulness of magnetic-assisted flooring, emergency buttons, pull cords, voice activation, local alarms and phone notifications. Responses highlighted the importance of affordability, ease of operation, maintenance and reliability during power or internet failures.

The survey is exploratory in nature and should not be interpreted as representative of all senior citizens. This paper therefore reports the main themes that emerged from the responses rather than numerical totals or percentages.

C. Site Study

The design proposal is developed for an existing bathroom in an independent residential house. The available measured bathroom dimensions are approximately 10 feet 6 inches by 6 feet, equivalent to approximately 3200 mm by 1829 mm.



D. Design Development

AutoCAD is used for two-dimensional planning and technical drawings. SketchUp is used for three-dimensional modelling and spatial development, while D5 Render is used to visualise materials, lighting and the proposed interior environment.

These tools support the design and presentation process. They do not independently validate the technical performance of the proposed magnetic flooring or electronic systems.

III. LITERATURE REVIEW

3.1 Bathroom Safety and Fall Prevention

Bathroom safety is an important part of residential environments for older adults. Wet surfaces, changes in floor level, limited movement space and the absence of suitable support can contribute to fall-related risks.

Afifi, Al-Hussein and Bouferguene (2015) examined geriatric bathroom design in relation to minimising the risk of falling among older adults. Their work supports the importance of considering bathroom-specific design features when developing safer residential environments.

This study uses that understanding as a foundation for prioritising floor safety, movement support, fixture accessibility and suitable spatial organisation.

3.2 Accessible Housing and Universal Design

The WHO Housing and Health Guidelines (World Health Organization, 2018) provide a broader framework for considering the relationship between housing conditions and health. Accessible home environments are important because the home should support people with different abilities and changing needs.

For bathroom interiors, this means considering ease of access, clear movement routes, understandable controls and fittings that can be used with reduced physical effort.

3.3 Falls Prevention and Older Adults

The World Guidelines for Falls Prevention and Management for Older Adults by Montero-Odasso et al. (2022) provide an important reference for understanding fall prevention as a broader and multidimensional concern.

In the context of interior design, this reinforces the need to consider both the user's physical capabilities and the environmental conditions that influence movement and balance.

3.4 User-Centred Bathroom Design

User-centred design requires the environment to respond to the practical needs, abilities and preferences of its intended users. Bathroom planning for older adults should therefore consider activities such as transferring to and from the toilet, reaching fittings, bathing while seated and accessing emergency assistance. Afacan and Barshan (2024) similarly adopt a user-centred approach to identifying the priorities of older adults in creating a fall-free bathroom.

The literature reviewed for this study supports the importance of combining functional accessibility with an understanding of the user's everyday experience.

3.5 Research Gap

The reviewed literature establishes the importance of accessible bathroom planning and fall prevention. The present study uses these principles as a starting point and explores how they may be brought together with emergency response and sensory comfort within a single residential bathroom proposal.

The magnetic-assisted flooring concept and integrated acoustic wellness proposal are exploratory design interventions. Their effectiveness cannot be established through literature review or visualisation alone and requires further testing.

IV. FINDINGS AND DESIGN REQUIREMENTS

4.1 Key Bathroom-Related Difficulties

The exploratory survey and literature review identified several recurring concerns:

- Slippery bathroom floors and the possibility of losing balance.
- Difficulty maintaining stability while moving between bathroom fixtures.
- Difficulty sitting down and standing up from the toilet.
- The need for easily accessible support during bathing and toilet use.
- Difficulty requesting help during an emergency.
- Concerns about the reliability of electronic systems during power or internet failures.

These findings indicate that an age-friendly bathroom should address both everyday movement and unexpected situations.

4.2 User Expectations from Adaptive Features

The exploratory responses suggested interest in emergency buttons, pull cords, voice activation, local alarms and phone notifications. However, the usefulness of these features depends on their accessibility, simplicity and reliability.

The proposed magnetic-assisted flooring also requires careful consideration. Its acceptance and practical value cannot be assumed because the concept is unfamiliar and has not been physically validated in this project.

4.3 Design Requirements

Based on the identified concerns, the following design requirements were developed:

1. Provide a slip-resistant floor finish suitable for wet bathroom conditions.
2. Maintain clear and understandable circulation between the washbasin, WC and shower areas.
3. Provide appropriate support for sitting, standing and movement.
4. Ensure that emergency controls can be reached from both standing and fallen positions.
5. Provide a local alert that does not depend entirely on internet connectivity.
6. Make controls simple and easy to understand.
7. Provide optional sound features that can be adjusted or switched off.
8. Select materials and fittings that can be maintained within a residential setting.

V. PROPOSED INTEGRATED DESIGN FRAMEWORK

The proposed design is organised around four connected principles: SAFE, INDEPENDENT, RESPONSIVE and WELLNESS.



5.1 SAFE

Safety is the primary requirement of the proposed bathroom. It includes slip-resistant flooring, appropriate support fittings, suitable lighting, clear circulation and careful positioning of sanitary fixtures.

Grab bars are proposed near relevant activity areas to provide support during movement and transfers. A shower seating provision is also considered to reduce the need for prolonged standing during bathing.

The flooring should use a suitable slip-resistant finish as the primary surface-safety measure; the slip resistance of the chosen finish should be confirmed against a recognised test method such as ISO 13287:2019. The proposed magnetic-assisted system is supplementary and should not replace conventional wet-area safety measures.

5.2 INDEPENDENT

Independence refers to the ability of senior citizens to perform daily bathroom activities with reduced assistance.

The proposed design considers reachable fittings, clear movement routes, accessible controls and a practical arrangement of the washbasin, WC and shower zones.

The intention is to reduce unnecessary physical effort while allowing users to maintain privacy and confidence during everyday activities.

5.3 RESPONSIVE

The responsive layer focuses on the ability of the bathroom to support a user during an emergency.

A proposed emergency response system combines a wall-mounted button, a low-level pull cord and optional voice activation. When activated, the system is intended to trigger a local alert and, where connectivity is available, send a notification to a connected device.

The local alert is important because remote notification should not be the only means of requesting help. The system also requires an accessible reset mechanism, power backup planning and a clear response procedure.

5.4 WELLNESS

The wellness layer addresses the sensory and emotional experience of the bathroom.

Optional acoustic features may provide nature sounds, water sounds or soft instrumental audio. These features are intended to create a more comfortable and relaxing atmosphere.

Sound features should have simple controls, adjustable volume and automatic shut-off. They must not interfere with emergency alerts or make it difficult for the user to hear important sounds.

The proposed acoustic feature is an interior comfort intervention, not a medical treatment.

VI. PROPOSED DESIGN INNOVATIONS

6.1 Magnetic-Assisted Flooring with Dedicated Bathroom Slippers

The first proposed innovation is a magnetic-assisted flooring concept designed to provide supplementary support during movement.



The concept consists of bathroom flooring with a selected magnetic component within the tile or an internal flooring layer, combined with dedicated clog-style bathroom slippers containing magnetic elements in their soles.

The intended concept is to create a controlled magnetic interaction between the flooring and the footwear. This interaction is explored as a possible supplementary stability feature for older adults. The system is not intended to replace the friction provided by a conventional slip-resistant floor. Magnetic attraction alone does not establish that a surface is safe in wet or soapy conditions.

The concept requires technical investigation before practical application. Important testing requirements include:

- Measurement of magnetic interaction and holding force.
- Evaluation of the force required to lift and release the foot during normal walking, including any increased risk of tripping.
- Testing under wet and soapy conditions.
- Assessment of natural gait and ease of movement.
- Testing of material durability and cleaning requirements.
- Evaluation of possible magnetic-field exposure and interactions with implanted medical devices.

The proposal should therefore be understood as an experimental design concept rather than a proven mobility-support product.

6.2 Smart Emergency Response System

The second innovation is a smart emergency response system intended to help senior citizens request assistance when they experience difficulty or an accident in the bathroom.

The proposed system includes:

A. Wall-Mounted Emergency Button

A clearly visible button is proposed at an accessible position so that the user can activate the system without complex instructions.

B. Low-Level Emergency Pull Cord

A pull cord is proposed to remain accessible when a user has fallen and cannot reach the wall-mounted button. Its design should provide a clear grip and avoid creating an entanglement hazard.

C. Voice Activation

Voice activation may be included as an additional method of triggering an emergency alert. It should not replace physical controls because voice recognition may not work in every situation.

D. Local Audible and Visual Alert

The system is intended to activate a local buzzer and visual indicator when an emergency signal is received. The alert should be noticeable without creating unnecessary disturbance.

E. Remote Notification

Where a suitable connection is available, the system may send a notification to a caregiver's or family member's smartphone.



Proposed operating sequence:

Emergency button, pull cord or voice command → control unit → local audible and visual alert → optional remote notification.

The system should include power backup planning, a clear acknowledgement process and a manual reset method. Its operation should not depend entirely on internet connectivity.

6.3 Acoustic Wellness Features

The third innovation explores the use of optional sound features to improve the sensory experience of the bathroom.

The proposed system may include a water-resistant speaker connected to a simple audio control. Users may select calming nature sounds, water sounds or soft instrumental audio according to personal preference.

The system should include:

- Simple and accessible controls.
- Adjustable volume.
- Automatic shut-off.
- Water-resistant equipment suitable for the installation location.
- An emergency override that takes priority over wellness audio.

The purpose of this feature is to support comfort and relaxation. Its effects on psychological well-being would require user evaluation and should not be presented as a clinical outcome.

VII. SITE-SPECIFIC DESIGN APPLICATION

7.1 Existing Bathroom Dimensions

The proposed design is developed for an existing residential bathroom measuring approximately:

Parameter	Specification
Length	10 feet 6 inches
Width	6 feet
Approximate metric dimensions	3200 mm × 1829 mm
Approximate area	5.85 square metres

The design uses the existing bathroom dimensions as the basis for planning. The final arrangement must be coordinated with the actual door position, window location, plumbing points, ceiling height and existing structural conditions.

7.2 Functional Zoning

The proposed bathroom is organised into three main functional zones:

A. Washbasin Zone

This area supports washing, grooming and other personal hygiene activities. The design considers accessible counter height, a suitable basin arrangement and a clear approach area.

B. WC Zone

The toilet area is planned with appropriate movement space and support fittings. A grab bar is proposed to assist with sitting and standing. The emergency response system should also be accessible from this zone.

C. Shower Zone

The shower area considers wet-floor safety, suitable shower fittings, support provision and the possibility of seated bathing. The arrangement should minimise unnecessary movement across wet surfaces.

Entry and circulation space should connect these zones without creating avoidable obstacles.

7.3 Material and Colour Scheme

The proposed interior uses a combination of burgundy, warm ivory, stone beige, matte black and natural wood tones.

Burgundy is introduced as a defining accent colour, while warm ivory and stone beige help maintain visual balance. Matte black is used for selected fittings and accessories. Natural wood tones introduce warmth into the overall interior character.

The proposed false ceiling uses a warm ivory limewash-inspired texture. This is intended to create a softer visual appearance in contrast with the more defined tile surfaces.

Material selection should also consider cleaning, moisture resistance, durability, maintenance and suitability for residential bathroom use.

7.4 Design Development and Visualisation

The design development process uses three software applications:

- **AutoCAD:** preparation of measured plans, proposed layouts, elevations, sections and technical drawings.
- **SketchUp:** three-dimensional modelling and spatial development of the proposed bathroom.
- **D5 Render:** visualisation of materials, lighting, colour combinations and the final interior atmosphere.

The software supports the communication of the proposed design. However, rendered images demonstrate the intended appearance and do not prove that the magnetic flooring or emergency system will perform as intended.

VIII. DISCUSSION, LIMITATIONS AND FUTURE SCOPE

8.1 Discussion

The proposed design brings together physical safety, independent use, emergency assistance and sensory comfort within a compact residential bathroom.

The SAFE principle establishes the foundation through slip-resistant flooring, support fittings and accessible spatial planning. INDEPENDENT focuses on reducing unnecessary physical effort and supporting daily activities. RESPONSIVE introduces emergency assistance through accessible controls and alert mechanisms. WELLNESS considers the user's sensory experience through optional acoustic features.

The integration of these four principles provides a broader approach to age-friendly bathroom design. Rather than treating safety, technology and comfort as separate concerns, the proposal considers them as connected parts of the same environment.

The design also highlights the importance of simplicity. Technology should support the user rather than introduce additional complexity. Physical emergency controls, clear circulation and conventional safety measures remain essential even when smart features are included.

8.2 Limitations of the Study

The study has several limitations:

1. The magnetic-assisted flooring concept has not been physically tested. Its magnetic strength, stability, release force, wet-condition performance and long-term durability remain to be established.
2. The smart emergency response system is a proposed design feature and has not been validated as a working installation.
3. The reliability of electronic components during power failure, network disruption or equipment malfunction requires further investigation.
4. Acoustic wellness preferences may differ between users, and the proposed sound feature has not been evaluated through a detailed user trial.
5. The available bathroom area of approximately 10 feet 6 inches by 6 feet creates limitations for circulation, fixture placement and accessibility.
6. The cost, installation requirements and long-term maintenance of specialised flooring and electronic components have not been fully assessed.
7. The design is developed through drawings and three-dimensional visualisation; a full-scale prototype and user evaluation have not been completed.

8.3 Future Scope

Future research can develop the proposal through physical prototyping and user-centred evaluation. The magnetic-assisted flooring concept requires controlled experiments to examine magnetic force, foot release, friction, wet-surface performance and walking comfort. The system should also be assessed for compatibility with users who have implanted medical devices.

The emergency response system can be developed into a working prototype and tested under different conditions, including power failure, network disruption and accidental activation. Testing should evaluate the ease of reaching controls and the clarity of alerts.

Acoustic wellness features can be evaluated through user feedback to understand preferred sound types, volume levels and control methods.

Further development can also include cost analysis, maintenance planning, accessibility evaluation and assessment of the final layout with older adults and caregivers.

IX. CONCLUSION

This research explores an integrated approach to designing an adaptive age-friendly residential bathroom. It identifies that bathroom safety for senior citizens should not be limited to preventing falls. It should also support independent movement, provide accessible emergency assistance and create a comfortable sensory environment.

The proposed framework is organised around four principles: SAFE, INDEPENDENT, RESPONSIVE and WELLNESS. These principles guide the planning of the bathroom and the integration of three proposed interventions: magnetic-assisted flooring with dedicated bathroom slippers, a smart emergency response system and optional acoustic wellness features.

The site-specific design applies these principles to an existing residential bathroom measuring approximately 10 feet 6 inches by 6 feet. The proposed layout considers the washbasin, WC and shower zones, together with support fittings, accessible controls and a coordinated material and colour scheme.

The magnetic-assisted flooring concept and smart emergency system represent exploratory design proposals and require further technical development and validation. Conventional slip-resistant flooring, accessible support fittings and reliable physical emergency controls remain essential.

Overall, the study proposes that an age-friendly bathroom should be understood as an adaptive residential environment that supports not only physical safety but also confidence, independence and comfort. By bringing together interior design, accessibility and carefully considered technology, the bathroom can become a more supportive space for older adults.

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