science, engineering and health studies

Research Article

Science, Engineering and Health Studies
https://lio1.tci-thaijo.org/index.php/sehs
ISSN (Online): 2630-0087

Bathroom design for enhanced comfort in Indonesian older adults and the disabled community

Nurul Retno Nurwulan

Faculty of Business, Higher Colleges of Technology, Madinat Zayed Women's Campus, Abu Dhabi 002, United Arab Emirates

ABSTRACT

Individuals with certain physical conditions encounter challenges in using the bathroom optimally due to various design limitations. For instance, older adults may fear falling in the bathroom, while individuals with disabilities may have troubles due to wheelchairs. The objective of this study was to propose an efficacious bathroom design tailored to the needs of older adults and the disabled community in Indonesia. In this context, "efficacious" means to reduce the gap between physical requirements and object limitations to enhance user comfort. Anthropometric measurements were used to ascertain the appropriate dimensions for the bathroom. Importantly, the proposed design is versatile enough to accommodate young adults without disabilities, addressing space constraints in smaller homes.

Keywords: bathroom; design; disabled; ergonomics; older adults

Corresponding author:
Nurul Retno Nurwulan
nnurwulan@epoka.edu.al

Received: *22 March 2024*
Revised: *10 May 2024*
Accepted: *11 May 2024*
Published: *17 December 2024*

Citation:
Nurwulan, N. R. (2024). Bathroom design for enhanced comfort in Indonesian older adults and the disabled community. Science, Engineering and Health Studies, 18, 24040004.

1. INTRODUCTION

The older adult population in Indonesia, constituting 6.86% of the total population, was 274.86 million people in 2022 (World Bank Group, 2023). This data reflects a 0.08% increase from the previous year, where the percentage stood at 6.78%. Indonesia has the 8th largest older adult population globally (Population Reference Bureau, 2023). The rising number of older adults signifies an extension of life expectancy for this demographic. Past research has found an increase in life expectancy from 69.81 years in 2010 to 70.90 years in 2016 (Wulandari et al., 2019), positioning Indonesia as the 6th country in the ASEAN region for life expectancy (Berniyanti et al., 2019). Various factors contribute to the augmentation of life expectancies in Indonesia, encompassing economic, environmental, and health-related aspects, including nutrition and healthcare facilities.

Several nations aspire to enhance life expectancies by optimizing economic parameters. However, approaches vary, with some countries emphasizing the improvement of older adult care by increasing the number of nursing homes (Ananta and Arifin, 2009). In Indonesia, there are fewer than 300 nursing homes nationwide due to a cultural norm that children are expected to take care of their parents. In addition, a considerable portion of older adults express a preference for independent living, despite the potential challenges (Ryeung and Jin, 2004). However, the older adult population has a problem with their postural stability which is associated with ageing and limits their daily activities (Vermeulen et al., 2012). This issue is not exclusive to older adults but is also pertinent to disabled individuals. Consequently, poorly designed household layouts and materials can pose significant safety risks (Nurwulan and Selamaj, 2022).

At least one in three adults and disabled individuals experience falls, predominantly attributed to unsupportive and unsafe home conditions, particularly in bathrooms (Afifi et al., 2015; Nurwulan et al., 2019). Besides maximizing individual capabilities, mitigating the risk of falls can be achieved by adapting to the environment (Capezuti et al., 2008). Many studies have proposed recommendations to diminish fall risks, emphasizing the need for a clear articulation of the gap between one's activity limitations and environmental demands (Murphy et al., 2006). Designing an accessible bathroom for older adults and the disabled presents a complex challenge encompassing safety, functionality, and inclusivity. The existing designs often fail to adequately address the diverse needs of these individuals, resulting in discomfort, inconvenience, and sometimes even accidents. Key issues include insufficient space for manoeuvrability, lack of appropriate fixtures and features to support mobility, and non-intuitive layouts that hinder independence. Consequently, there is a significant need for innovative design solutions that prioritize usability and comfort for older adults and disabled individuals, empowering them to navigate their bathroom routines with confidence and ease. This study aimed to propose a bathroom design to facilitate the growing elderly population in Indonesia. In addition, this study also tries to accommodate the needs of the disabled community in Indonesia. This approach highlights the potential development of a universal bathroom design, accompanied by a comprehensive analysis of its advantages and limitations.

2. MATERIALS AND METHODS

2.1 Older adults and the disabled community

The term elderly refers to individuals aged 65 years or older, characterized by relatively low endurance and balance (Fuller, 2000; Nurwulan et al., 2019). Similarly, individuals with disabilities encounter various limitations in their activities (Salam and El-Din, 2019). Disabilities can manifest in different forms, including vision impairment, hearing difficulties, mental health conditions, intellectual disability, acquired brain injury, autism spectrum disorder, and physical disabilities. These limitations expose older adults and disabled individuals to an elevated risk of falling (Salam and El-Din, 2019; Nurwulan et al., 2019). Although the mortality rate associated with falls is relatively low, it contributes significantly to both financial burdens and psychological impacts (Centers for Disease Control and Prevention [CDC], 2020). For instance, the United States incurred a cost of $ 4.2 trillion for fall-related injury treatment in 2019 (CDC, 2024). Another risk involves psychological consequences, with 73% of individuals who have fallen experiencing anxiety and fear syndromes (Tinetti, 1994), leading to reduced engagement in individual mobility and activities (Li et al., 2003).

In a broader context, older adults and disabled individuals are susceptible to falls in various settings. However, a past study identified bathrooms as a significant environmental hazard within the homes of older adults (Blanchet and Edwards, 2018). Falls in bathrooms often result in a heightened risk of injuries.

2.2 Bathroom design considerations

Historically, bathrooms trace back to Mohenjo Daro, introduced 2,000 years before the Common Era, featuring only basic amenities like baths with direct drains into rivers. Subsequent developments included the construction of water closets at the House of Crate a millennium later, followed by hygiene and material arrangement improvements in the 1990s. The bathrooms evolved further to accommodate the diverse needs of individuals, including older adults and the disabled. Several considerations have emerged, emphasizing the importance of functionality, safety, and inclusivity in bathroom design.

One of the primary considerations is space optimization. Traditional bathroom designs prioritize aesthetics over functionality, leading to tight spaces that hinder mobility and accessibility. Conversely, modern designs focus on providing ample space for manoeuvrability, ensuring that individuals with mobility aids such as wheelchairs or walkers can easily navigate the bathroom (Salam and El-Din, 2019). This shift towards spacious layouts not only enhances accessibility but also contributes to a more comfortable and dignified experience for users.

Presently, the focus of bathroom design has shifted towards providing convenience for specific groups, such as older adults and the disabled (Boge et al., 2019). Another crucial aspect of evolving bathroom design is the incorporation of universal design principles. Universal design emphasizes the creation of products and environments that are usable by all people, regardless of age, ability, or status (Steinfeld and Maisel, 2012). In the context of bathrooms, this means incorporating features like lever-style faucets, grab bars, and curbless showers that benefit people of all ages, from young children to older adults. By embracing universal design principles, bathrooms are becoming more inclusive and welcoming spaces for everyone.

2.3 Anthropometric measurements

Anthropometric measurements in this study were derived from data compiled by the Indonesian Ergonomics Association and the Ergonomics and Work System Design Laboratory (Salam and El-Din, 2019). These measurements were acquired using various tools, including anthropometry, Campbell calliper, and scales. Thirty-six dimensions, encompassing aspects such as body size, hands, and feet were measured across different positions. The data generated from these observations not only included measurements but also details on several chair designs, with size specifications outlined in Table 1.

Anthropometric measurements play an important role in designing a bathroom. Appropriate spaces to accommodate a diverse population, including individuals of varying sizes and abilities, can be designed by understanding the range of human sizes and capabilities. Anthropometric considerations in bathroom design, such as the height of fixtures and the width of doorways ensure a functional, comfortable, and accessible space for older adults and disabled people. For instance, the placement of washbasins, toilets, and other fixtures must align with the average user's height and reach to facilitate ease of use and reduce strain. The washbasin should be positioned at a height suitable for both older adults and wheelchair users, while the toilet should have grab bars installed at appropriate heights to assist individuals with mobility limitations (Yarfi et al., 2017).

Moreover, employing anthropometric measurements allows for the design of clearances and manoeuvring space within the bathroom. Doorways, corridors, and open floor areas must be wide enough to accommodate wheelchair

users and individuals with mobility aids, ensuring unobstructed passage throughout the space (Pheasant and Haslegrave, 2018). Furthermore, the placement of fixtures and accessories should allow for sufficient clearance and reach zones, enabling users to move freely and carry out tasks with ease (Hignett and McAtamney, 2000).

Anthropometric considerations also extend to the design of shower and bathing facilities. The dimensions of shower stalls, tubs, and walk-in showers must accommodate users of various heights and sizes while prioritising safety and comfort (Afifi et al., 2015; Salam and El-Din, 2019). Features such as grab bars, non-slip surfaces, and adjustable showerheads further enhance usability and accessibility for individuals with diverse needs (Edwards et al., 2003; Afifi et al., 2015).

Additionally, the design of seating options within a bathroom, such as shower benches or integrated seating areas, can be made using anthropometric data. These elements should be sized and positioned to accommodate users, while minimising the risk of slips, falls, or discomfort. In conclusion, anthropometric measurements are essential in designing inclusive and accessible bathrooms. By considering the dimensions, proportions, and capabilities of the human body, designers can create spaces that meet the diverse needs of users while promoting comfort, safety, and independence.

Table 1. Anthropometric data

Body dimension	Percentile	Dimension (cm)	Data implementation
Body height	95th	187.63	Entrance, door height, grab bar #3
Shoulder width	95th	51.16	Entrance, door width
Eye height	95th	176.2	Washbasin
Eye height in sitting position	95th	133.78	Washbasin
Elbow height	50th	95.65	Washbasin, grab bar #1, grab bar #2, grab bar #4
Popliteal height	95th	49.1	Toilet, shower chair, bathtub
Knee height	50th	48.12	Washbasin
Knee length	50th	49.9	Washbasin, toilet, shower chair, bathtub
Hip width	95th	43	Washbasin, toilet, shower chair, bathtub
Elbow height in sitting position	50th	64.72	Grab bar #2, grab bar #3, grab bar #4
Length of forward hand	50th	66.18	Bathtub faucet, washbasin

Note: Grab bar #1 has the longest size and is mounted between towel racks, grab bar #2 is located next to the toilet, grab bar #3 is installed vertically and attached to the upper back of the shower seat, and grab bar #4 is inside the bathtub.

2.4 Bathroom dimensions

The dimensions of bathroom data were obtained from the findings of previous studies. Inclusion criteria were carefully used to determine if an article was relevant or not for this research. The inclusion criteria for the review were as follows:

- Relevance
  Articles must focus specifically on bathroom design, modifications, or products tailored to meet the needs of older adults and disabled individuals.
- Population
  Studies should contain older adults (aged 65 and over) or individuals with disabilities (physical, sensory, or cognitive impairments) should be included.
- Interventions
  Articles discussing interventions, modifications, or assistive devices aimed at improving accessibility, safety, and usability in bathrooms should be included.
- Design considerations
  Articles covering topics such as grab bars, non-slip flooring, wheelchair accessibility, walk-in showers, shower seats, raised toilets, and other design elements conducive to the needs of older adults and disabled individuals should be included.
- Outcome measures
  Studies reporting outcomes related to safety, functionality, independence, quality of life, or any other relevant outcome measures associated with bathroom modifications or interventions for the target population should be included.

The exclusion criteria were non-peer-reviewed articles and full-texts not written in English or Indonesian. All articles were evaluated for eligibility based on the title, abstract, inclusion criteria, and exclusion criteria. Articles that did not meet the eligibility criteria were excluded. A detailed summary of the bathroom dimensions is shown in Table 2.

3. RESULTS AND DISCUSSION

3.1 Dimension

A past study indicated that the incorporation of dimensions measuring 1.08 m in both length and width did not afford comfort to users (Hasiholan et al., 2019). Such small space restricts the installation of various components and appliances, and the resulting spatial constraints may impede user mobility. In contrast, a separate study suggested a suitable bathroom size of at least 7 x 8 ft (Nagananda et al., 2010). A larger bathroom facilitates enhanced mobility for independent individuals and those using wheelchairs, particularly older adults. Adhering to the principle that a bathroom should possess sufficient but not excessive free space to ensure adequate mobility, the proposed bathroom design has dimensions of 2 m in length and 4 m in width. Figure 1 provides a top-view representation of the proposed bathroom layout.

Table 2. Bathroom dimensions

Category	Independent user	Wheelchair user
Dimension	Not recommended for widths and lengths less than 1 m (Hasiholan et al., 2019)	At least 2 m x 2.5 m or more to ease wheelchair mobility (Nagananda et al., 2010)
Entrance area	The width should be more than 0.8 m (Ministry of Public Works of Indonesia, 2006)	More than or equal to 0.9 m to adjust the wheelchair width (Ministry of Public Works of Indonesia, 2006)]
Door	Bidirectional type of door (Nagananda et al., 2010)	Sliding door is recommended (Salam and El-Din, 2019)
Toilet	Sit-to-stand toilet with more height added (Kinoshita, 2012)	Toilet with a standard height between 0.43 m and 0.485 m (Capezuti et al., 2008; Yarfi et al., 2017)
Bathtub	Sitting or sleeping design with a higher head position is recommended (Pheasant, 1996)	Walk-in bathtub with a door should be installed (Pheasant, 1996)
Shower area	Folding shower stall seat is recommended to be installed on the wall (Murphy et al., 2006)	
Shower	Hand-held shower is better than a fixed shower (Salam and El-Din, 2019)	
Grab bar	Using three or more stable grab bars is recommended (Edwards et al., 2003)	
Washbasin	Use elbow height as a standard (Ministry of Public Works of Indonesia, 2006)	Height less than 0.865 m is recommended (Yarfi et al., 2017)
Towel rack	Double-function grab bar and towel rack (Memken and Earley, 2007; Junprateep et al., 2020)	
Floor	Wood, stone, and vinyl tile material (Afifi et al., 2015)	
Lighting	Using at least 600 lux as the main lamp (Afifi et al., 2015)	
Faucet	Lever type of handless faucet with an angle of either 45° or 90° (Meindl and Freivalds, 1992)	

Figure 1. Top-view of the proposed bathroom design

3.2 Entrance area

The entrance area encompasses various factors associated with doors, including their size and type. According to data from the Ministry of Public Works of Indonesia, the width requirements for the entrance area are categorized based on physical conditions, specifying 0.9 m for wheelchair users and 0.8 m for those not using wheelchairs (Ministry of Public Works of Indonesia, 2006). These dimensions align with anthropometric considerations for shoulder width, with a recorded value of 51.16 cm for the 95th percentile (Nurmianto, n.d.). The guidelines incorporate flexibility to facilitate user comfort, and the proposed design adopts a width of 0.9 metres, accounting for wheelchair users. The entrance area in the proposed design can be seen in Figure 2.

Furthermore, the selection of door type is a crucial consideration for convenience, as excessively heavy doors demand more energy. Bidirectional doors are recommended for bathroom designs catering to independent older adults, primarily to facilitate swift access to emergency aid (Nagananda et al., 2010). Another study suggests that sliding doors represent an ideal type of implementation (Salam and El-Din, 2019). However, there are constraints associated with sliding doors, particularly those with substantial weight due to material choices. To address this, an alternative involves using a combination of materials such as fibreglass, aluminium, or stainless steel, which results in relatively lightweight doors.

3.3 Toilet

The utilization of a sit-to-stand (STS) toilet design is discouraged due to its high energy demand for older adults (Afifi et al., 2015). However, a study posited that the STS design can be rendered suitable through adjustments in height and incorporating a handrail adjacent to the toilet (Kinoshita, 2012). Concurrently, various studies propose alternative concepts for designing toilets that cater to the specific needs of older adults. Capezuti et al. advocated for a toilet height aligned with the standard leg length of each individual (Capezuti et al., 2008). Sanford et al. (1995) suggested an alternative approach involving the addition of grab bars on the sides of the toilet, employing various layout combinations.

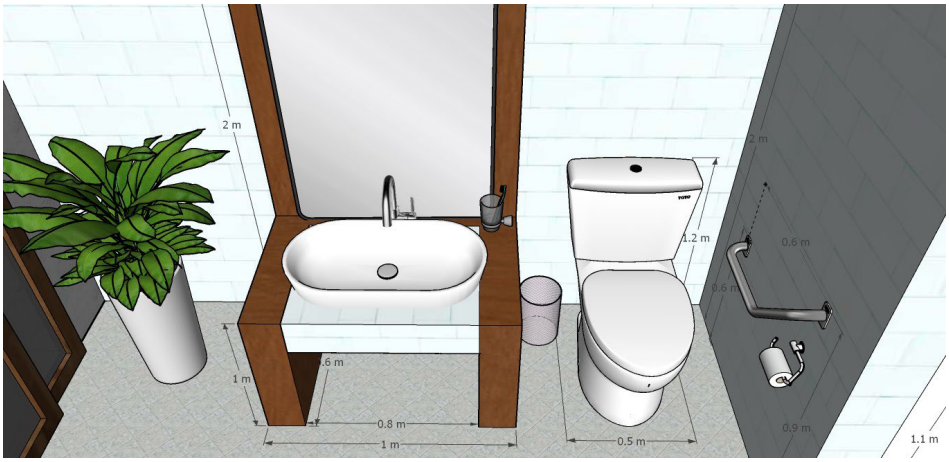

Figure 2. Proposed entrance area

Drawing upon theoretical considerations, the STS toilet design is advised in favour of installing a toilet bowl with a standard height ranging from 0.43 m to 0.48 m for enhanced comfort for older adults (Capezuti et al., 2008; Yarfi et al., 2017). A toilet with a permanent flush is also recommended to prevent water from splashing onto the floor. Moreover, the application of grab bars is endorsed using a combination of diagonal and horizontal configurations (Sanford et al., 1995). This configuration aids older adults in transitioning from a standing to a sitting position. According to the results of a questionnaire administered to 50 non-ambulatory participants, and the second-best choice according to 66 non-ambulatory participants, this configuration emerges as the optimal choice. Figure 3 illustrates the toilet and washbasin.

3.4 Washbasin

While not considered the most pivotal component of a bathroom, certain adjustments are necessary to optimize its use for older adults. The washbasin should be positioned by adapting it to at least 50% elbow height, equivalent to 95.65 cm (Ministry of Public Works of Indonesia, 2006). Another recommendation suggested a height of less than 86.5 cm for wheelchair users (Yarfi et al., 2017). An accessible faucet with a lever-type mechanism and a 45° mounting angle will make the basin easy to use (Meindl and Freivalds, 1992). Other aspects, such as the depth of the basin and the positioning of the mirror, were adjusted based on anthropometric data outlined in Table 1. Detailed design specifications are depicted in Figure 3.

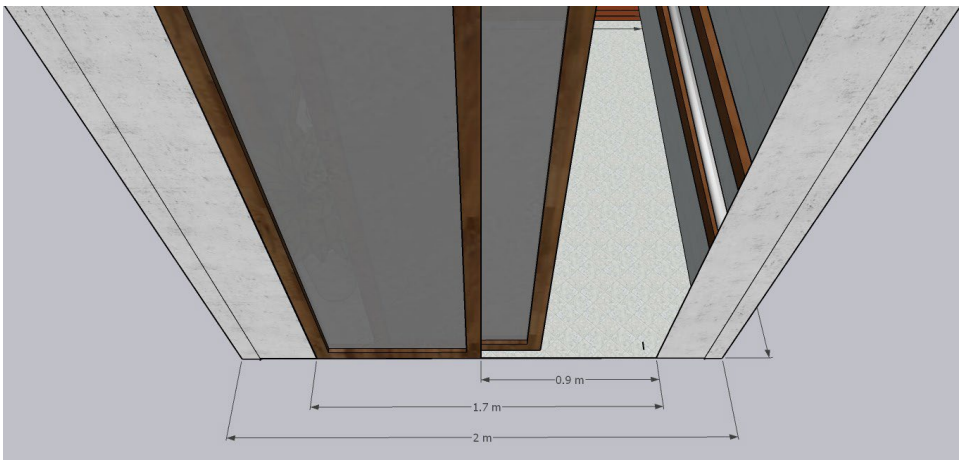

Figure 3. Proposed toilet and washbasin

3.5 Bathtub

A bathtub is recognized as a potentially hazardous space for individuals with limited mobility (Afifi et al., 2015). Its dimensions should be tailored to accommodate the height and body shape of individuals. Past research delineated two design recommendations for bathtubs, one with a sitting position leaning back and another with a sleeping position featuring a higher head position (Pheasant, 1996). Besides these specific design considerations, there are general recommendations for bathtub sizes:

- The bathtub should have a standard length of at least 95% of the individual's body height.
- Incorporate a curved angle ranging from 30° to 65° in the neck region to maintain the head above the water.
- Ensure a width that is at least 95% of the maximum body width when taking a breath.

In response to these recommendations, a walk-in bathtub serves as an alternative, using acrylic as the base material due to its lightweight properties and clean appearance. The design features a door for ease of entry for older adults, with one side being permanent and equipped with grab bars set at an angle between 30° to 65°, adhering to bathtub comfort standards. The placement of the faucet is positioned in front of the user, within the maximum range of the user's forward-reaching hand. Safety measures include a sealing mechanism to prevent water leakage and employing a watertight seal using a compressed method. Despite these advancements, the widespread application of this type of a bathtub in bathroom designs remains limited because of the complexities associated with materials and manufacturing methods. The top view of the proposed bathtub is shown in Figure 4.

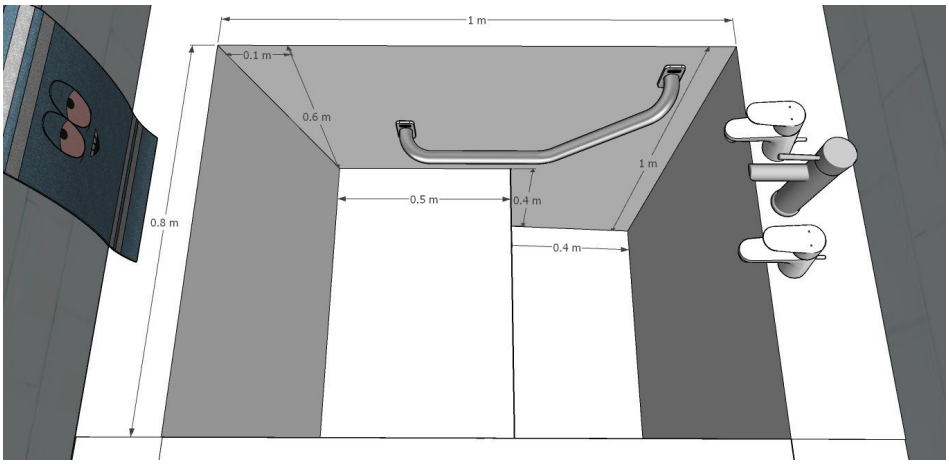

Figure 4. Top-view of the proposed bathtub

3.6 Shower area

The shower area represents a complex component due to the restricted mobility of older adults (Murphy et al., 2006). The prolonged duration of standing during showering is a notable concern for older adults. To address this, designers recommend the installation of a tub seat for showering. A hand-held shower is advocated for in the design of bathrooms for older adults to mitigate mobility challenges (Nagananda et al., 2010; Salam and El-Din, 2019), as depicted in Figure 5.

Figure 5. Proposed shower area

Innovations in shower area design can be implemented by incorporating specific details aligned with the needs of older adults. The design considerations for the shower area are outlined as follows:

- The flooring of the wet part of the shower area should use a distinct material due to higher water intensity. Materials such as wood, stone, or vinyl facilitate faster drying compared to other materials (Afifi et al., 2015). Thus, a wooden plank structure with a dedicated drainage section is proposed (refer to Figure 6).
- Empirical evidence suggests that hand-held showers surpass fixed showers in terms of suitability (Salam and El-Din, 2019). Both types, however, can be installed concurrently to serve distinct functions. Fixed showers may be employed for washing hair, while hand-held showers are more convenient for bathing. Both can be positioned on the back of the shower stall seat.
- To minimize mobility concerns, a folding shower stall seat can be centrally installed in the shower area (Murphy et al., 2006).
- A fixed rack for soap, shampoo, toothpaste, towels, and other equipment should be affixed to the wall next to the shower area, aligned with the height of the shower seat to facilitate ease of access for older adults. The design of this rack incorporates a wall-mounted structure, as opposed to a plastic or metal shelf attached to the wall, ensuring durability and tidiness.
- Vertically installed grab bars on the backside of the seat, positioned at a height corresponding to the 95th percentile of body height, are recommended (Pheasant, 1996). A horizontal grab bar extending from the entrance area to the shower seat enhances ease of movement for older adults.

3.7 Grab bar

Incorporating grab bars is crucial for older adults to mitigate the risk of falls during bath transfers (Edwards et al., 2003). Certain grab bars may exhibit insufficient strength due to material influences, posing a potential hazard for older adults, given the imperative that grab bars must support the entire body weight. To address this, the use of extruded metal within the grab bar, combined with an outer layer of plastic, is recommended.

Nearly 40% of 550 older adults use three or more grab bars, 20% have two grab bars, 30% have only installed a grab bar, and the remaining do not have them (Edwards et al., 2003). Grab bars manifest in various forms, commonly categorized into four configurations in bathroom design (Sanford et al., 1995). These configurations, distinguished by horizontal or vertical layouts, offer distinct advantages. In the proposed design, four grab bars are installed, each differing in size, shape, and location. The first, positioned at elbow height, is the longest (see Figure 7). The second grab bar is placed near the toilet, adopting a diagonal and horizontal configuration (see Figure 8). The third grab bar is mounted vertically behind the shower stall seat (see Figure 9). Lastly, the fourth grab bar, matching the shape of the others, is located inside the bathtub (see Figure 10).

3.8 Floor and lighting

The prevalence of slips and falls among older adults often arises from slippery floor surfaces. In response, floor materials such as wood, stone, or vinyl tile are recommended, taking into consideration factors such as their non-slip properties and ability to absorb water efficiently. The proposed design employs two primary materials: wood, used in wet areas with a plank design, and ceramic tile, employed in dry areas.

In addition to floor materials, another critical element in bathroom hazard assessment is lighting. Poor lighting is a common contributor to the risk of falls in older adults, particularly due to the effects of ageing on eyesight (Afifi et al., 2015). As an alternative, a minimum illumination level of 600 lux for main lights and 300 lux for lighting lamps is recommended (Afifi et al., 2015). To adhere to these guidelines, a long neon light is strategically installed around the centre of the bathroom, supplemented by smaller lights positioned in the corners of the room.

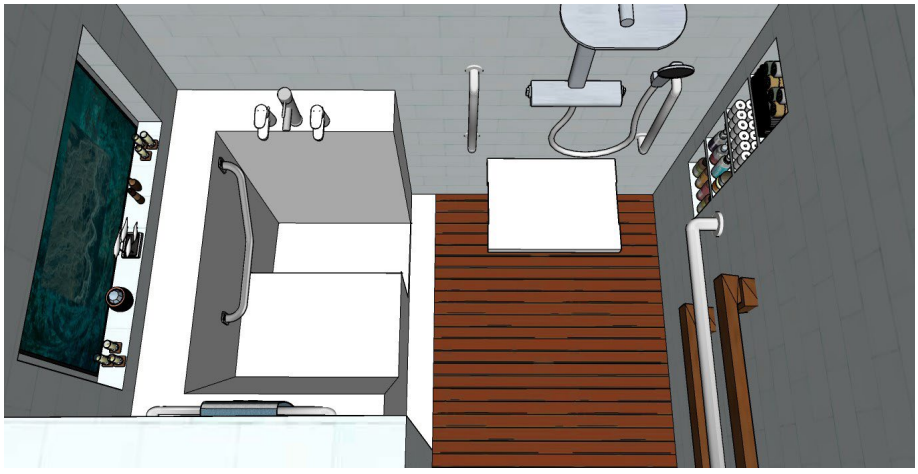

Figure 6. Top-view of the proposed shower area

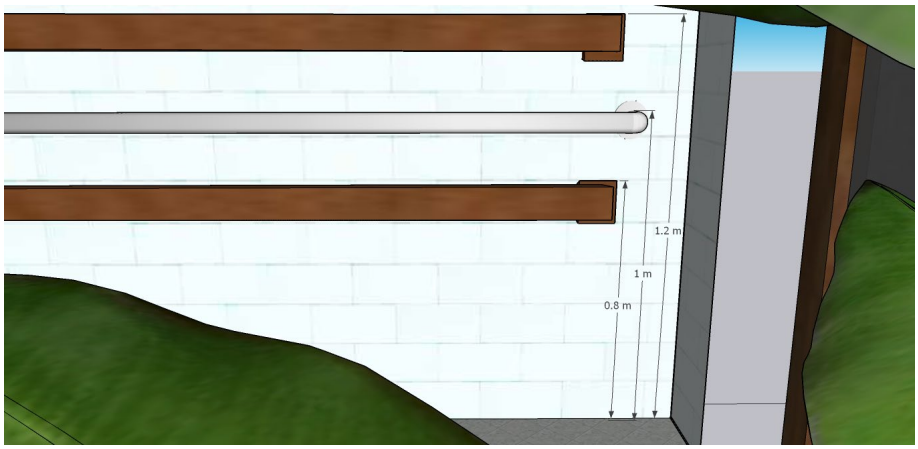

Figure 7. Grab bar #1

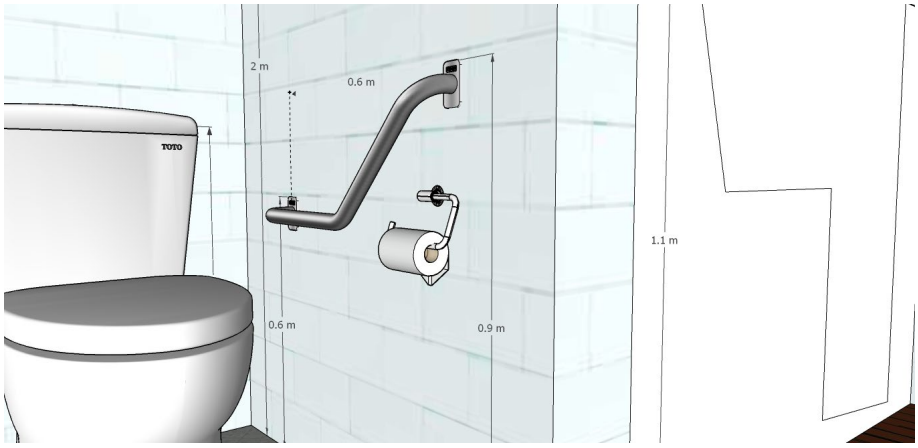

Figure 8. Grab bar #2

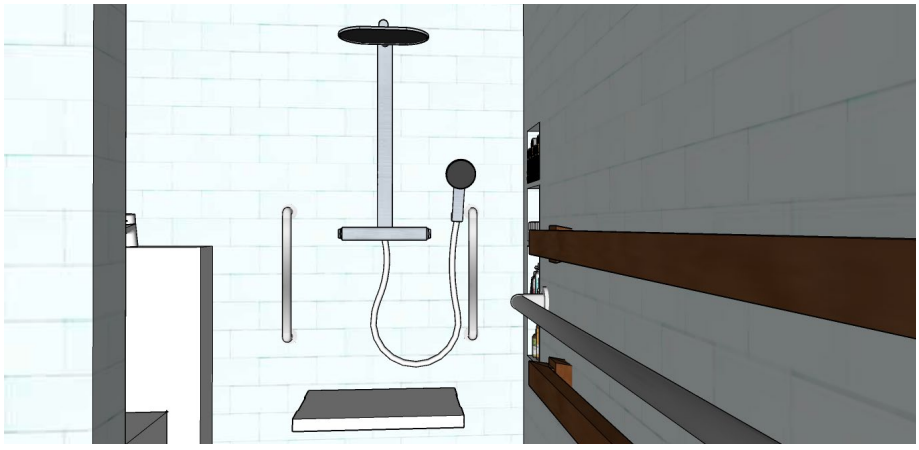

Figure 9. Grab bar #3

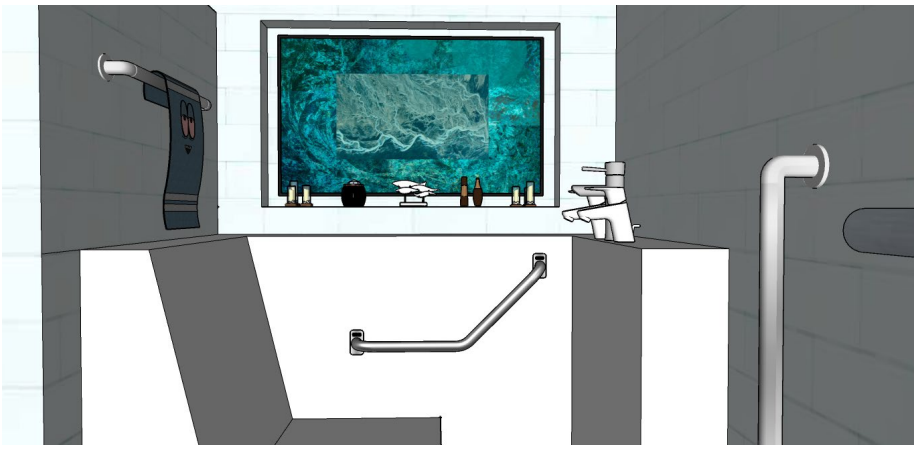

Figure 10. Grab bar #4

3.9 Towel rack

Auxiliary fixtures, like towel racks, are essential for older adults, and their layout and shape should adhere to specific recommendations. Multiple studies propose the installation of grab bars with towel racks as a favourable approach (Memken and Earley, 2007; Junprateep et al., 2020). While this is a commendable recommendation, it is noteworthy that the installation of grab bars involves inherent risks and expenses. The costs associated with installing grab bars are substantial due to the primary material and adhesive strength requirements. As a response to this concern, the proposed design opts for a wooden rack instead of a grab bar. However, the dual-function grab bar concept is integrated inside the bathtub, serving as both a grab bar and handrail for added functionality.

4. CONCLUSION

The bathroom, with its inherent constraints that compromise user comfort, requires a carefully planned design. Inappropriate material choices for flooring or lighting may introduce unwarranted risks. This research proposed several recommendations grounded in the limitations posed by physical conditions, as identified in prior studies. Each dimension incorporated in the design has been meticulously adjusted based on anthropometric data. Implementing these design recommendations aims to mitigate the risk of falls among older adults and disabled individuals.

Subsequent research endeavours should consider employing alternative methodologies capable of providing quantitative data, enhancing the overall validity of research findings. However, it is acknowledged that such methods may incur substantial costs and time investment. Conversely, future research could explore integrating advanced technologies, such as sensors and automatic machines, to further enhance user safety and comfort.

REFERENCES

Afifi, M., Al-Hussein, M., and Bouferguene, A. (2015). Geriatric bathroom design to minimize the risk of falling for older adults–a systematic review. *European Geriatric Medicine,* 6(6), 598–603.

Ananta, A., and Arifin, E. N. (2009). Older persons in Southeast Asia: From liability to asset. In *Older Persons in Southeast Asia: An Emerging Asset* (Arifin, E. N., and Ananta, A., Eds.), p. 3. Singapore: Institute of Southeast Asian Studies.

Berniyanti, T., Palupi, R., Setijanto, D., Bramantoro, T., Nur, I., and Ramadhani, A. (2019). Overview of dentures demand to support the improvement of life quality of the elderly at high-level life expectancy in Indonesia. *Journal of International Oral Health,* 11(3), 112–117.

Blanchet, R., and Edwards, N. (2018). A need to improve the assessment of environmental hazards for falls on stairs and in bathrooms: Results of a scoping review. *BMC Geriatrics,* 18(1), 272.

Boge, J., Callewaert, S., and Petersen, K. A. (2019). The impact of bathroom design on privacy for users with special needs. *Ageing International,* 44, 300–317.

Capezuti, E., Wagner, L., Brush, B. L., Boltz, M., Renz, S., and Secic, M. (2008). Bed and toilet height as potential environmental risk factors. *Clinical Nursing Research,* 17(1), 50–66.

Centers for Disease Control and Prevention (CDC). (2020). *Web-based injury statistics query and reporting system*. U.S. Department of Health and Human Services. [Online URL: http://www.cdc.gov/injury/wisqars/index.html] accessed on May 7, 2021.

Centers for Disease Control and Prevention (CDC). (2024). *Economics of Injury and Violence Prevention.* U.S. Department of Health and Human Services. [Online URL: http://www.cdc.gov/injury-violence-prevention/economics/index.html] accessed on August 29, 2024.

Edwards, N., Lockett, D., Aminzadeh, F., and Nair, R. C. (2003). Predictors of bath grab-bar use among community-living older adults. *Canadian Journal on Ageing,* 22(2), 217–227.

Fuller, G. F., (2000). Falls in the elderly. *American Family Physician,* 61(7), 2159–2173.

Hasiholan, B. P., Susilowati, I. H., and Satrya, C. (2019). The conformity of anthropometric measurements of bathroom and bedroom designs for independent elderly at Panti Sosial Tresna Werdha (PSTW)* Budi Mulia I Jakarta in 2018. *Journal of Accessibility and Design for All,* 9(1), 25–40.

Hignett, S., and McAtamney, L. (2000). Rapid entire body assessment (REBA). *Applied Ergonomics,* 31(2), 201–205.

Junprateep, C., Seviset, S., and Eakwutvongsa, S. (2020). Guideline for innovation management design of home bathroom environment to help reduce accident risk among elderly. *Mediterranean Journal of Social Sciences,* 11(2), 33–42.

Kinoshita, S. (2012). Handrail position and shape that best facilitate sit-to-stand movement. *Journal of Back and Musculoskeletal Rehabilitation,* 25(1), 33–45.

Li, F., Fisher, K. J., Harmer, P., Mcauley, E., and Wilson, N. L. (2003). Fear of falling in elderly persons: Association with falls, functional ability, and quality of life. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences,* 58(5), 283–290.

Meindl, B. A., and Freivalds, A. (1992). Shape and placement of faucet handles for the elderly. *Proceedings of the Human Factors Society Annual Meeting,* 36(10), 811–815.

Memken, J., and Earley, N. (2007). Accessible housing availability for the growing U.S. elderly population. *Housing and Society,* 34(1), 101–115.

Ministry of Public Works of Indonesia. (2006). *Index to Public Works Management & Policy*. [Online URL: https://peraturan.bpk.go.id/Download/95215/PermenPU30-2006.pdf] accessed on May 7, 2021. [in Indonesian]

Murphy, S. L., Nyquist, L. V., Strasburg, D. M., and Alexander, N. B. (2006). Bath transfers in older adult congregate housing residents: Assessing the persona environment interaction. *Journal of the American Geriatrics Society,* 54(8), 1265–1270.

Nagananda, M. S., Sengupta, A., Santhosh, J., Anand, S., Rehman, S. M. K., Khan, A. M., Rautray, P., Gharai, D., and Das, L. K. (2010). Design and pragmatic studies of bathroom for elderly people in India. *WSEAS Transactions on Biology and Biomedicine,* 7(4), 287–305.

Nurmianto, E. (n.d.). *Lampiran 1: Data Antropometri Orang Indonesia Menurut*. [Online URL: http://repository.maranatha.edu/4907/2/0523085_Appendices.pdf] accessed on April 14, 2021. [in Indonesian]

Nurwulan, N., and Selamaj, G. (2022). Left-handedness and musculoskeletal discomfort in students. *Journal of Accessibility and Design for All,* 12(2), 320–334.

Nurwulan, N. R., Jiang, B. C., and Novak, V. (2019). Development of postural stability index to distinguish different stability states. *Entropy,* 21(3), 314.

Pheasant, S. (1996). *Bodyspace: Anthropometry, Ergonomics, and the Design of Work*, 2nd, London: Taylor & Francis.

Pheasant, S., and Haslegrave, C. M. (2018). *Bodyspace: Anthropometry, Ergonomics and the Design of Work*, 3nd, Boca Raton: CRC press.

Population Reference Bureau. (2023). *Countries with the oldest populations in the world*. [Online URL: https://www.prb.org/countries-with-the-oldest-populations/] accessed on June 23, 2023.

Ryeung, J. S., and Jin, C. Y. (2004). Analysis on the importance degree of design checklist for the elderly housing unit. *Journal of Families and Better Life,* 22(6), 111–119.

Salam, M. A. A., and El-Din, A. K. S. (2019). Developing smarter bathrooms for elderly and disabled people. *Journal of Al-Azhar University Engineering Sector,* 14(52), 1024–1035.

Sanford, J. A., Arch, M., and Megrew, M. B. (1995). An evaluation of grab bars to meet the needs of elderly people. *Assistive Technology,* 7(1), 36–47.

Steinfeld, E., and Maisel, J. L. (2012). *Universal Design: Creating Inclusive Environments*. Hoboken, NJ: John Wiley & Sons.

Tinetti, M. E. (1994). Prevention of falls and fall injuries in elderly persons: A research agenda. *Preventive Medicine,* 23(5), 756–762.

Vermeulen, J., Neyens, J. C., Spreeuwenberg, M. D., van Rossum, E., Hewson, D., Duchêne, J., and De Witte, L. (2012). Construct validity of a modified bathroom scale that can measure balance in elderly people. *Journal of the American Medical Directors Association,* 13(7), 665.e1-5.

World Bank Group. (2023). *World development indicators*. [Online URL: https://data.worldbank.org/indicator/SP.POP.65UP.TO.ZS?locations=ID] accessed on June 25, 2023.

Wulandari, R. D., Supriyanto, S., Qomaruddin, B., and Laksono, A. D. (2019). Socioeconomic disparities in hospital utilization among elderly people in Indonesia. *Indian Journal of Public Health Research and Development,* 10(11), 2192.

Yarfi, C., Ashigbi, E. Y. K., and Nakua, E. K. (2017). Wheelchair accessibility to public buildings in the Kumasi metropolis Ghana. *African Journal of Disability,* 6, a341.