

**Aligning Built Environments with Aging Body Capabilities:
A Case Study of the Rama-Thanarak Senior Project**

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Received: 11/05/2026

Revised: 27/05/2026

Accepted: 29/05/2026

Abstract

This research analyzes the alignment between the physical limitations of elderly individuals and safety-oriented architectural design standards, using the Rama-Thanarak residential project as a case study. Risk factor statistics from a sample of 10,346 elderly individuals indicate that the most common limitations are the need for manual support when standing up (24.06%) and difficulty navigating changes in floor levels (20.24%). The bathroom was identified as the most challenging area in daily life (66.51%). Based on these findings, a safety design evaluation checklist was developed from the “Safe Home, No Fall Risk” guidelines, focusing on three key areas: bathroom spaces, internal circulation systems, and visual environments. The evaluation of the project’s smallest (31.71 sq.m.) and largest (49.66 sq.m.) unit plans shows strong alignment with Universal Design standards. Key design features include sliding doors wider than 0.9 meters, elimination of door thresholds to reduce tripping risks, and the provision of grab bars and shower seating to support users with reduced muscle strength. The study adopts a qualitative evaluative case study methodology using document analysis and architectural plan assessment. Alignment is defined as the degree of correspondence between the project’s design features and a synthesized 10-point Universal Design checklist. Limitations include reliance on plan documentation without on-site

verification and analysis of only two unit types. The findings highlight that architecture responsive to the physical needs of older adults plays a crucial role in reducing accidents and enhancing quality of life sustainably.

Keywords: Elderly Housing, Falls, Design Standards, Universal Design, Rama-Thanarak Project

1. Introduction

1.1 Background and Significance of the Problem

The worldwide demographic trend toward an aging population presents an inescapable reality, exerting profound structural influences on economic, social, and architectural frameworks. Thailand, specifically, has already achieved the status of a Complete Aged Society and is swiftly progressing toward a Super-Aged Society by 2026. Projections indicate that those aged over 60 will constitute over 20% of the overall population. This substantial increase transcends mere demographic change; it presents a considerable challenge to the quality of life, especially concerning residential safety. As individuals age, they undergo continuous physiological decline, including reduced muscle mass, impaired balance, diminished sensory perception, and neurological degradation (Chang, 2023; Khlangklang & Nantaboot, 2020).

Falls in the home represent a "silent threat," a problem that becomes more pronounced as the population ages. Data from the Division of Injury Prevention, Department of Disease Control, shows that over a third of elderly Thais suffer at least one fall each year. The 2024 figures paint a troubling picture: more than 165,000 elderly people were hospitalized due to falls, with over 40,000 of those cases involving serious hip fractures annually. The impact of these falls goes beyond the initial injury; 17% of elderly patients with hip fractures die within a year of the event. As a result, falls have become the second leading cause of unintentional injury-related deaths, trailing only road accidents. The country bears a considerable economic and public health burden from this situation, with annual costs exceeding 2.6 billion THB.

The factors contributing to these accidents can be categorized into intrinsic factors stemming from physical degeneration and extrinsic factors, arising from physical environments that are hostile to elderly limitations. Survey research indicates that 80% of the elderly still reside in original homes lacking adequate safety features, such as slippery floors, a lack of grab bars, thresholds or uneven floor levels that present tripping hazards, and insufficient lighting in critical areas. The bathroom is the most dangerous place, accounting for 30% of all falls. These falls often lead to the Fear of Falling (FoF) syndrome, which causes older people to move less. This reduced activity then causes muscle loss (Sarcopenia), increasing the chance of falling again (Li et al., 2023; Wongcharoen et al., 2022).

As a result, the idea of Aging in Place has become a key policy in the field of elderly care, addressing these issues. This approach aims to help older adults live independently in familiar places for as long as possible (De Bruijn, 2025; Poolgerd & Sajjanavakul, 2020; Jarutach & Lertpradit, 2020). However, making this possible requires changing physical environments based on Universal Design principles (Pochakaparipan & Lamaiwong, 2023; Jarutach, 2015). Consequently, the Thai government initiated a pilot project integrating real estate with healthcare innovation titled the Rama-Thanarak Senior Complex. This collaboration between the Treasury Department, the Faculty of Medicine Ramathibodi Hospital, and the Faculty of Architecture at Chulalongkorn University is designed for Active Aging individuals. The project focuses on proactive accident prevention through architectural designs that meet international standards. Nevertheless, there remains a critical need for in-depth analysis to determine whether the residential plans and environments provided accurately apply architectural theories and building regulations, and whether they can effectively reduce common domestic accidents (Chang, 2023; Jarutach, 2023; Poolgerd & Sajjanavakul, 2020).

The study serves as a key step in establishing new benchmarks for elderly-oriented real estate development in Thailand, shifting the focus from social welfare to the sustainable provision of rights and safety. The logical chain linking aging to architectural risk can be articulated as follows: (1) aging causes functional decline; (2) functional decline increases environmental sensitivity; (3) residential environments consequently become determinants of injury risk; (4) architecture therefore functions as an active health determinant. While previous research has documented fall-risk factors and design standards in separate bodies of literature, there remains a gap in studies that systematically evaluate the alignment between empirically documented physical limitation profiles and specific architectural design compliance within a single Thai senior housing project. This study addresses that gap.

1.2 Literature Review

This literature review encompasses key issues related to the residential context of the elderly, categorized into four primary dimensions: accident situations and risk factors, residential design standards, trends in the elderly real estate market, and the details of the case study project.

1.2.1 Characteristics of Home Accidents and Risk Factors among the Elderly

The literature indicates that accidents in the elderly possess unique characteristics closely linked to physiological aging. Falls are the most common type of accident, usually occurring in five main areas: home accidents, road accidents, risky activities, sudden medical problems, and natural disasters (Khlangklang & Nantaboot, 2020). These accidents are often caused by problems with balance, such as issues with the vestibular system, along with vision problems that affect depth perception and distance, and reduced strength in the legs (Chaiyaphum Medical Journal, 2024; Sampatpong, 2023; Li et al., 2023). Existing research identifies the home environment as the most critical trigger, with the highest risk areas ranked as follows: bathrooms (84.1%), followed by house perimeters and staircases. Physical challenges observed in urban environments encompass unsuitable furniture dimensions, the absence of bathroom grab bars, and the presence of glossy, potentially hazardous flooring (Jarutach & Lertpradit, 2020). Consequently, an individual's assessment of risk substantially impacts their involvement in preventive actions; in particular, older adults demonstrating a heightened awareness of risk are more likely to adopt self-preservation behaviors compared to those with less pronounced risk perceptions (Wongcharoen et al., 2022). The statistic of 84.1% cited for bathrooms requires clarification of its denominator. It is distinct from the figure reported in Section 3 (66.51% of the 427 individuals who reported home difficulties), and the source and base population of the 84.1% figure should be explicitly stated to avoid misinterpretation.

1.2.2 International Standards and Universal Design Criteria

Design standards for the elderly have undergone continuous revision, integrating Universal Design (UD) principles. These principles are intended to establish environments that are both accessible and secure for all individuals (Jarutach, 2015). In Thailand, these standards are mandated by Ministerial Regulations (2005 and 2021), and are additionally reinforced by guidelines issued by the Department of Health and the Universal Design Center (UDC) at Chulalongkorn University (Chang, 2023; Jarutach, 2015). Architectural standards are typically defined by several key areas. First, spatial circulation is important. Doors must be at least 90 cm wide, and they should not have thresholds to prevent tripping and to allow wheelchair access. In addition, hallways need to be wide enough for a wheelchair to turn around, which requires a diameter of 1.50 meters. 2.) Safety Equipment: Grab bars must be made of non-slip, ergonomic materials and securely installed at a height of 80–90 cm from the floor, particularly in bathrooms and areas with level changes. 3.) Visual and Chromatic Dimensions: The use of

color contrast between walls, floors, and sanitary ware helps reduce visual confusion. Nighttime illumination is crucial, employing automated sensors or switches conveniently located for bedside operation. Furthermore, health considerations and technological progress are of utmost importance; contemporary residential designs are progressively incorporating innovations like antimicrobial materials (e.g., Microban) and Internet of Things (IoT) technologies, encompassing emergency call systems linked to a central care unit (Pochakaparipan & Lamaiwong, 2023; Jarutach, 2023). In addition to Thai ministerial regulations, the following international standards serve as the comparative framework for this study: (1) ADA Standards for Accessible Design (2010) dimensional requirements for accessible spaces; (2) ISO 21542:2021 Building Accessibility and Usability of the Built Environment; (3) WHO Age-Friendly Housing guidelines housing criteria supporting functional independence across decline trajectories; (4) British Standard BS 8300:2018 Design of an Accessible and Inclusive Built Environment; (5) Lifetime Homes Standard 16 design criteria ensuring adaptability for aging residents. These international benchmarks strengthen the comparative basis for the checklist developed in Phase 2 and are consistent with the universal design method referenced throughout this study.

1.2.3 Trends in the Elderly Real estate Market

Research indicates substantial expansion within Thailand's elderly real estate sector, transitioning away from conventional welfare-oriented nursing homes and towards upscale condominium projects and gated communities (Charoenyingwattana, 2018; Poolgerd & Sajjanavakul, 2020). Factors that significantly impact purchasing choices encompass considerations beyond mere cost, such as security, the availability of crucial amenities within a 400–500-meter distance, and the accessibility of healthcare provisions (Charoenyingwattana, 2018; Junma, 2023; De Bruijn, 2025). Although many Thai consumers view these dwellings as expensive, high-end offerings (Charoenyingwattana, 2018), novel approaches are gaining traction. These encompass the adaptive repurposing of underutilized structures and Naturally Occurring Retirement Communities (NORCs), which prioritize community involvement (De Bruijn, 2025; DePaul et al., 2022). Moreover, artificial intelligence and neural networks are being employed to predict market demand and furnish personalized housing suggestions, drawing upon historical patterns of behavior. At the same time, there's a growing focus on data privacy in digital environments (Li et al., 2021; Tang & Zhao, 2025). Comparative analysis across studies reveals both convergent and divergent findings: while Charoenyingwattana (2018) and Junma (2023) both identify security and healthcare proximity as key purchase drivers, they diverge on the relative weight of cost sensitivity in urban versus provincial markets. De Bruijn (2025) introduces an adaptive reuse perspective absent from Thai literature, suggesting a gap in local policy frameworks for repurposed elderly housing. The knowledge gap this study addresses is the absence of empirically grounded architectural alignment evaluation that connects population-level physical limitation data to specific design features in Thai senior housing.

1.2.4 Case Study: The Rama-Thanarak Senior Housing Project

The Rama-Thanarak project, situated in Bang Phli District, Samut Prakan Province, encompasses more than 72 rai, or roughly 28.5 acres. This undertaking functions as a pioneering pilot project, designed to merge extensive medical services with residential accommodations within a unified complex. As detailed in the official project data (<https://www.dadasset.com/>), the development is structured around three principal elements: the Ramathibodi Hospital, which serves as a center for learning and development in elderly health; a Nursing Home providing convalescent care; and the Senior Housing area, which is specifically allocated for residential purposes. The residential units range from 31.71 sq.m. (Type 1-1A) to 49.66 sq.m. (Type 2-2), and incorporate features directly relevant to the study variables: sliding doors (addressing mobility limitations), threshold-free flooring (addressing

the 20.24% with floor-level difficulties), grab bars and foldable shower seats (addressing the 24.06% requiring hand support when standing), and color-contrast materials (addressing sensory decline). These features make the project a directly appropriate case for evaluating architectural alignment with an empirical elderly physical limitation profile.

1.3 Research Objectives

After initial research and a review of current literature, the researcher has set the following objectives:

1.3.1 To analyze statistical data pertaining to the circumstances and environmental risk factors linked to domestic accidents affecting the elderly population.

1.3.2 To synthesize design criteria for spaces, materials, and equipment based on Universal Design principles specifically aimed at accident prevention.

1.3.3 To evaluate the architectural alignment of the Rama-Thanarak project with established standards, in order to enhance the effectiveness of proactive accident risk reduction.

1.3.4 To identify the scope of architectural safety criteria consistent with WHO Age-Friendly Housing guidelines and applicable international standards (ADA, ISO 21542, BS 8300), in order to inform future policy development for elderly residential projects in Thailand.

1.4 Conceptual Framework

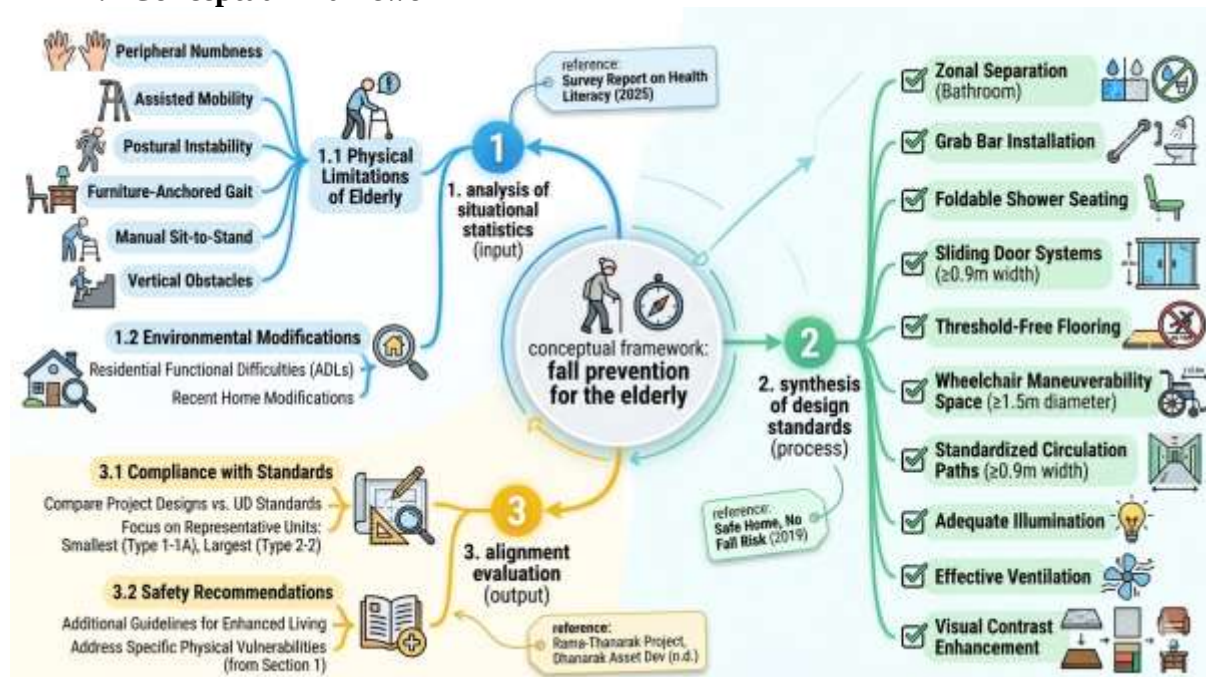


Figure 1: Conceptual framework for assessing residential safety for the elderly

The conceptual framework of this study is structured around a tripartite interaction model linking Body, Behavior, and Built Environment. (1) Body: Age-related physiological changes sarcopenia, vestibular dysfunction, reduced proprioception, and visual impairment produce measurable functional limitations (balance instability, difficulty standing, reduced mobility). (2) Behavior: These limitations shape behavioral adaptations including reliance on furniture for support, fear of falling, and home modification decisions. (3) Built Environment: The residential environment either mitigates or amplifies fall risk depending on whether its design features are aligned with the functional capabilities of the aging body. Architectural safety standards operationalize this alignment by specifying minimum design thresholds that accommodate functional decline. This study evaluates alignment between the Body dimension

(empirical limitation profile from Phase 1 data) and the Built Environment dimension (Rama-Thanarak design features), using Universal Design criteria as the evaluative standard.

2. Research Methodology

In this study, the researcher established a systematic operational framework divided into three key phases, detailed as follows: This study employs a qualitative evaluative case study methodology (Yin, 2018) using two primary techniques: (1) secondary data analysis of the 2025 national fall-risk survey, and (2) architectural plan assessment using a synthesized design checklist. This approach enables systematic examination of design compliance in a real-world project while grounding the evaluation in empirical population-level physical limitation data.

Phase 1: Analysis of Environmental Circumstances and Risk Factors. This initial phase involves the collection and synthesis of secondary data from the "2025 Health Literacy and Fall Risk Factors Survey" by the Department of Disease Control. The objective is to identify injury statistics and categorize the physical risk factors within residential settings that currently impact the Thai elderly population. The data obtained from this phase are used to summarize the critical issues that require architectural intervention. The 2025 Health Literacy and Fall Risk Assessment Survey was selected because it is the most recent nationally representative survey (n = 10,346, aged 60+) covering both physical limitation variables and home environment variables directly relevant to the architectural assessment variables in Phase 3. No additional data sources were required for this phase.

Phase 2: Synthesis of Universal Design Standards. During this phase, information from the "Safe Home, No Fall Risk" documentation and Universal Design principles is analyzed and categorized into appropriate standards for proactive accident prevention. These standards encompass spatial circulation dimensions, material and equipment specifications, and overall safety system installations. The synthesis process results in a comprehensive architectural safety assessment tool, essentially a checklist. The 10-point checklist was developed through a three-step synthesis process: (1) Standards identification Thai Ministerial Regulations (2005, 2021), the "Safe Home, No Fall Risk" guidelines (Saengwongjaroen, 2019), ADA (2010), ISO 21542:2021, and WHO Age-Friendly Housing guidelines were reviewed; (2) Categorization criteria were grouped into three functional domains (bathroom safety, circulation systems, visual environment) corresponding to the most prevalent physical limitations identified in Phase 1; (3) Operationalization each criterion was converted into a binary (Pass/Fail) observable indicator assessable from architectural plans, with explicit dimensional thresholds. Where Thai regulations and international standards differed, the more stringent criterion was adopted. Validity was supported by convergence across multiple standards; reliability was ensured through consistent dimensional criteria applied uniformly to both unit types.

The next step, Phase 3, involves evaluating this tool through a case study and then drawing conclusions. In the concluding stage, the assessment instrument, formulated during Phase 2, is employed to scrutinize and contrast the residential unit designs and spatial information pertaining to the Rama-Thanarak project. This procedure seeks to ascertain the degree of concordance between the implemented design and established safety protocols, assess the project's efficacy in mitigating accident probabilities, and generate comprehensive recommendations for the enduring advancement of housing for the elderly. The two unit types (Type 1-1A: 31.71 sq.m.; Type 2-2: 49.66 sq.m.) represent the minimum and maximum functional floor areas, providing boundary-case coverage of the project's design range. Assessment was conducted through dimensional analysis of architectural drawings from official project documentation. Limitation: assessment is plan-based only and does not include physical site inspection or post-occupancy evaluation.

3. Results

3.1 Analysis of Situational Statistics

Based on previous research and survey reports, Thailand is steadily transitioning into an aged society. Falls are the most common accidents for older people at home. These accidents are mainly caused by physical limitations and dangerous conditions in the home. According to the "2025 Health Literacy and Fall Risk Assessment Survey" conducted by the Fall Prevention Group under the Injury Prevention Division, Department of Disease Control (Injury Prevention Division, 2025), a study was performed on a sample of 10,346 elderly individuals aged 60 and over. This data provides a summary of the characteristics of this group, which reflects the larger elderly population.

Table 1 Percentage distribution of the sample group categorized by age range (Injury Prevention Division, 2025)

Age Range	Frequency (n=10,346)	Percentage (%)
60–69 years	6,635	64.31
70–79 years	2,849	27.54
80 years and above	862	8.33

Note: Mean = 68.39, Standard Deviation = 7.01, Minimum = 60, and Maximum = 100

An examination of the 10,346 elderly participants from the "2025 Health Literacy and Fall Risk Assessment Survey" indicates that the "young-old" cohort, encompassing those aged 60–69 years, constitutes the largest segment, comprising 6,635 individuals, or 64.31% of the sample. Subsequently, the 70–79 age group is represented by 2,849 individuals, equivalent to 27.54%. Conversely, the "old-old" cohort, encompassing individuals aged 80 and above, represents the least populous segment, comprising 862 individuals, which is equivalent to 8.33% of the entire sample. The aggregate sample demonstrates a mean age of 68.39 years (SD = 7.01), with ages ranging from a minimum of 60 years to a maximum of 100 years.

Table 2 Frequency and percentage of physical limitations among the elderly (Injury Prevention Division, 2025)

Physical Limitations of the Elderly	Frequency (n=10,346)	Percentage (%)
1. Frequent numbness in the feet		
No	8,390	81.09
Yes	1,956	18.91
2. Use of walking aids or being advised to use one		
No	9,059	87.56
Yes	1,287	12.44
3. Feeling unsteady while standing or walking		
No	8,978	86.78
Yes	1,368	13.22
4. Grabbing or leaning on furniture while walking at home		
No	8,555	82.69
Yes	1,791	17.31
5. Necessity of using hands to push up when standing		
No	7,857	75.94
Yes	2,489	24.06
6. Difficulty navigating or stepping up to different floor levels		
No	8,252	79.76
Yes	2,094	20.24

The survey results indicate that the most common physical constraint within the sample population is the requirement to utilize the hands for assistance when standing, affecting 2,489 individuals, or 24.06%. This is succeeded by challenges in traversing varied floor levels, as reported by 2,094 individuals (20.24%), and frequent foot numbness, observed in 1,956 individuals (18.91%). Furthermore, the study uncovered significant adaptive behaviors observed in the domestic environment: 1,791 older adults (17.31%) reported using furniture as a source of support while moving about. A portion of the sample also indicated experiencing instability during ambulation (1,368 individuals, or 13.22%), and 1,287 individuals (12.44%) either employed walking aids or had been advised by professionals to do so.

Beyond physical limitations, the physical features of a person's home can also increase the risk of falling. The survey report provides the following information about these environmental factors:

Table 3 Frequency and percentage of daily living difficulties within the home and home modifications over the past year (Injury Prevention Division, 2025)

Information	Frequency (n=10,346)	Percentage (%)
Residential areas posing difficulties in daily life		
None	9,919	95.87
Yes	427	4.13
Bathroom	284	66.51
Bedroom	135	31.62
Kitchen	143	33.49
Stairs	136	31.85
Front of house/Entrance	143	33.49
Home modifications in the past year		
None	8,975	86.75
Yes	1,371	13.25

Most of the older participants, specifically 95.87% (9,919 people), reported no difficulties with their daily activities at home. Conversely, 4.13% (427 individuals) indicated encountering challenges within particular residential spaces. When these spaces were categorized, the bathroom emerged as the most problematic area, with 66.51% (284 individuals) reporting difficulties. This was succeeded by the kitchen and the front of the house/entrance, each accounting for 33.49% (143 individuals). Furthermore, staircases and bedrooms were reported as problematic by 31.85% (136 individuals) and 31.62% (135 individuals), respectively. Regarding behavioral adaptation over the preceding year, 86.75% (8,975 individuals) had not undertaken any home modifications. Conversely, only 13.25% (1,371 individuals) reported making residential adjustments within the past year to improve safety or facilitate daily living. These three data dimensions should be interpreted in relation to each other: physical limitations (Table 2) create specific vulnerabilities to environmental features (Table 3), which in turn should motivate home modifications (Table 3, lower section). The 24.06% requiring hand assistance when standing are directly at risk in areas lacking grab bars; the 20.24% with floor-level difficulties are vulnerable wherever thresholds exist; the 17.31% relying on furniture for support are at risk from unstable furnishings. The low home modification rate (13.25%) despite these risks indicates an environmental-behavioral gap that architectural design must proactively address which is precisely the intervention logic of the Rama-Thanarak project evaluated in Section 3.3.

3.2 Synthesis of Design Standards

Based on the analysis of situational statistics and physical risk factors contributing to accidents among the elderly, the researcher utilized these critical issues as a foundation for determining architectural solutions. This synthesis process refers to the principles outlined in the "Safe Home, No Fall Risk" document by the Ministry of Social Development and Human Security, compiled by Saengwongjaroen (2019). An effective safety assessment checklist was developed, structured around three key dimensions. When designing residential environments for the elderly, the standards emphasize the bathroom, which is statistically the most hazardous area. Specifications encompass a distinct separation of wet and dry zones, the incorporation of sturdy grab bars for assistance, and the inclusion of foldable shower seats to streamline daily activities and lessen the physical strain of maintaining equilibrium. Concerning internal circulation and spatial systems, the criteria stipulate the implementation of sliding doors with a minimum net clear width of 0.9 meters to ensure unobstructed access for seniors and wheelchair users. Furthermore, a circular clear space with a minimum diameter of 1.5 meters must be provided to allow for wheelchair maneuvering. The minimum width for internal pathways should be 0.9 meters. The most important design feature is the absence of thresholds, which directly reduces the tripping hazards the sample group faced when navigating obstacles. Regarding the visual environment and hygiene, the design necessitates consistent, adequate lighting across all functional zones, alongside sufficient ventilation to facilitate fresh air circulation and moisture control. Using high-contrast color schemes on floors, walls, and furniture is also crucial. This method helps elderly people with vision problems understand where things are and accurately judge distances, which significantly contributes to proactive strategies for preventing accidents. Essentially, the criteria established by the "Safe Home, No Fall Risk" guidelines (Saengwongjaroen, 2019) extend beyond basic physical requirements, serving as a vital intervention. This approach is designed to address the specific physical limitations often seen in older adults, particularly those who have trouble moving or standing up. A thorough set of standards, covering bathrooms, accessible movement, and visually supportive environments, provides a practical framework for improving safety in homes. The researcher will apply this 10-point synthesized checklist as the Standard Criteria to evaluate the architectural alignment of the Rama-Thanarak project. The goal is to determine how well the different unit plans work to reduce the risk of falls, and whether they can truly help the daily lives of the Thai elderly, as this study aims to show. Each of the 10 checklist criteria was derived from a specific physical limitation and corresponding standard: (1) Wet/dry zone separation balance instability / ADA, Thai MR 2021; (2) Grab bars hand support need, 24.06% / ADA 609, ISO 21542; (3) Foldable shower seat muscle weakness / WHO Age-Friendly Housing; (4) Sliding doors mobility and wheelchair access / Thai MR 2005; (5) Door width $\geq$ 0.9 m, no threshold floor-level difficulty, 20.24% / ADA 404, ISO 21542; (6) Wheelchair turning radius $\geq$ 1.5 m wheelchair use / ADA 304; (7) Pathway width $\geq$ 0.9 m walking aid use, 12.44% / BS 8300; (8) Adequate lighting visual decline, nighttime risk / WHO, Thai DoH; (9) Ventilation habitability and moisture control / Thai Building Code; (10) Color contrast depth perception difficulties / ISO 21542, Lifetime Homes Standard.

3.3 Alignment Evaluation

The architectural alignment for fall prevention was assessed using the standard checklist derived from the "Safe Home, No Fall Risk" documentation, which served as the criterion for evaluating the residential unit plans of the case study project (Rama-Thanarak). Two-unit types were deliberately selected for analysis, chosen for their functional floor area: the smallest unit type (Type 1-1A) and the largest unit type (Type 2-2). The examination centered on the spatial organization of circulation, the integration of safety provisions within the bathroom environment, and the requisite clearance dimensions for the effective utilization

of mobility aids and wheelchairs. These factors are of paramount importance, directly addressing the physical constraints observed in the majority of the sample population. Figures 2 and 3 show the functional space's structure and how it follows the principles of Universal Design (UD).

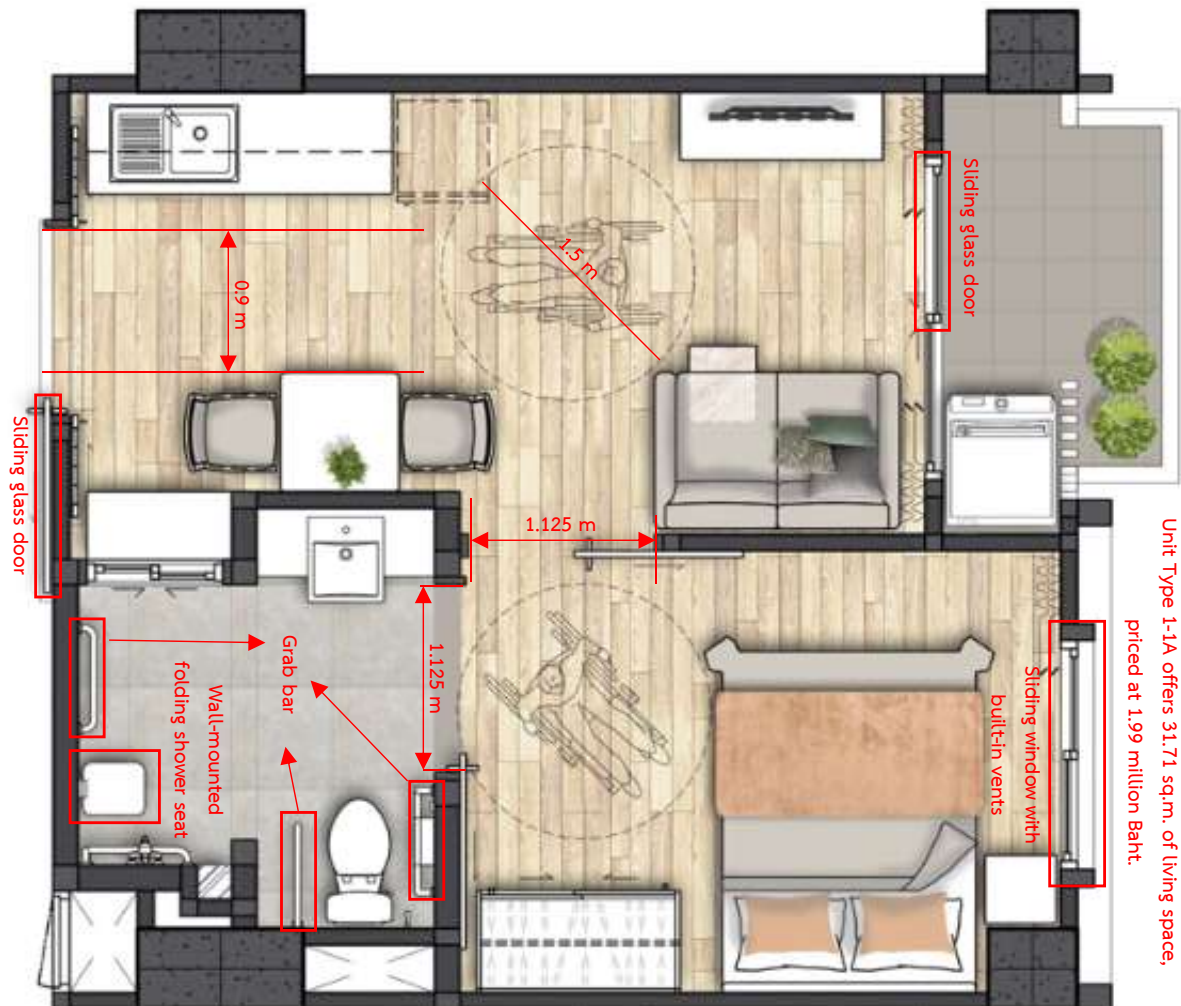


Figure 2: Architectural alignment analysis based on Universal Design standards for unit Type 1-1A (31.71 sq.m.) (Dhanarak Asset Development, n.d.)



Figure 3: Architectural alignment analysis based on Universal Design standards for unit Type 2-2 (49.66 sq.m.) (Dhanarak Asset Development, n.d.)

Table 4 Evaluation results of architectural alignment based on design standards

Category	Synthesized Standards	Evaluation (1-1A / 2-2)	Remarks
Bathroom Area	Wet and dry zones separation	Pass / Pass	Floor levels are recessed in the wet area instead of using door thresholds.
	Installation of grab bars	Pass / Pass	Grab bars are installed at the toilet and shower areas.
	Foldable shower seat	Pass / Pass	Foldable seats are provided to reduce the risk associated with standing while showering.
Circulation System	Sliding door systems	Pass / Pass	Sliding doors are utilized for the main entrance, bathroom, and balcony
	Door width ≥ 0.9 m with no thresholds	Pass / Pass	Level flooring throughout the unit with wide door openings
	Wheelchair turning radius (min. 1.5 m)	Pass / Pass	A 1.5 m diameter turning space is available in both the bedroom and living area.
	Internal pathway width ≥ 0.9 m	Pass / Pass	Clearance between furniture ranges from approximately 0.9 – 1.1 m.

Category	Synthesized Standards	Evaluation (1-1A / 2-2)	Remarks
Environment	Adequate lighting	Pass / Pass	Sufficient natural light is provided through large balcony doors and windows.
	Sufficient ventilation	Pass / Pass	Ventilation openings are integrated into both the living and sleeping areas.
	Color contrast (Floor/Wall vs. Furniture)	Pass / Pass	Surface materials with contrasting colors are selected to assist in depth perception.

Concerning the bathroom, the project exhibits rigorous compliance with safety standards. A distinct separation is established between wet and dry zones; the wet area employs a recessed floor design, thereby eliminating thresholds and reducing the potential for tripping. Moreover, grab bars are strategically positioned at both the toilet and shower locations, and foldable shower seats are incorporated to diminish fall risks for elderly occupants experiencing balance difficulties. Regarding internal circulation, the units are equipped with sliding door mechanisms for the primary entrance, bathroom, and balcony, thereby facilitating uncomplicated access. All doorways offer a net clear width exceeding 0.9 meters, and the flooring is uniformly level throughout the unit, devoid of any impediments. Furthermore, the living and bedroom spaces are designed with a circular clearance, at least 1.5 meters across, to allow for easy wheelchair movement. Main walkways are kept clear, creating a passage roughly 0.9 to 1.1 meters wide – a measurement that suits older adults. The design emphasizes a friendly atmosphere and cleanliness, achieved by letting in plenty of natural light. This is done with large balcony doors and windows that bathe the area in light, simplifying everyday tasks. An effective ventilation system is also part of the plan, with vents in both living and sleeping quarters. Finally, the materials selected feature a pronounced contrast in color between floors, walls, and furnishings. This key design element aids seniors with visual impairments in judging distances and finding things, thereby enhancing safety.

4. Discussion

An examination of the concordance between the physical constraints of the elderly population and the architectural features of the Rama-Thanarak project demonstrates a meaningful conceptual alignment between risk data and preventative design strategies. Several crucial points warrant discussion: 1. Critical Spaces and Mobility Challenges: Statistical data unequivocally show that over 66.51% of the elderly encounter the most significant difficulties within the bathroom environment. Considering the project's design elements specifically, the incorporation of recessed floor levels in lieu of door thresholds and the installation of secure grab bars it becomes apparent that these architectural modifications directly mitigate hazards in high-risk areas. This strategic design approach substantially reduces user apprehension and improves safety within an area previously linked to elevated fall rates. 2. Addressing Functional Limitations: Considering that 24.06% of the sample population experiences challenges with standing and 20.24% encounter difficulties in ambulation, the incorporation of sliding door systems featuring a net clear width surpassing 0.9 meters and an unobstructed circulation path is essential. These elements extend beyond contemporary aesthetic considerations; they serve as an "indirect supportive infrastructure," thereby enabling the elderly to preserve their autonomy. This approach is consistent with the core principles of Universal Design (UD). UD aims to reduce accessibility barriers and promote fairness in housing. As a result, it ensures

that everyone can live with dignity, regardless of their physical abilities. The theoretical integration of Universal Design should be deepened: the features implemented in the Rama-Thanarak project reflect Mace's (1997) seven UD principles, particularly Principle 2 (Flexibility in Use) and Principle 5 (Tolerance for Error), which directly address the functional decline profile documented in the Phase 1 data. This alignment demonstrates that the project's design philosophy is grounded in evidence-based universal accessibility, not merely regulatory compliance.

5. Safety Recommendations

Based on the architectural evaluation and the physical limitations commonly associated with the elderly demographic, the following recommendations are put forth to improve home safety, with a particular emphasis on accident prevention within high-risk areas and the promotion of independent living:

1. Improving Safety in Key Areas:

The bathroom continues to present the most significant challenges for its users. Although the project adheres to wet/dry zone separation and basic hardware standards, the coefficient of friction (COF) of floor surfaces requires continuous monitoring. In the sample group, 18.91% reported frequent foot numbness, which significantly impaired their ability to maintain balance on slippery surfaces. Furthermore, the installation of motion-sensor lighting systems along the route from the bed to the bathroom is recommended. This measure would improve visibility and reduce the risk of falls at night, especially for people who have reported feeling unsteady when walking.

2. Designing for Future Functional Decline:

Furniture stability must be reinforced to withstand weight-bearing or gripping, as 17.31% of participants exhibited the behavior of leaning on furniture for support. Furthermore, emergency alert systems should be installed at appropriate heights specifically at a level reachable even in the event of a fall on the floor to ensure timely assistance in high-risk zones.

3. Promoting Environmental Literacy and Adaptation:

This program must provide residents with actionable guidance for organizing their homes. The primary objective is to maintain an unobstructed 0.9-meter clear circulation path. This means offering suggestions about what should be included, or left out, of the interior spaces. For instance, they should avoid floor mats that don't have anti-slip backing. These recommendations will work in tandem with the building's design, creating a fall-prevention environment that truly fits the daily lives of the elderly residents.

6. Conclusions

The findings of this research demonstrate that the Rama-Thanarak project serves as a high-safety residential model for the elderly. This is achieved through the concrete application of architectural standards designed to resolve structural risks. The assessment of both the smallest and largest unit plans demonstrates their successful adherence to all ten safety criteria, encompassing bathroom dimensions, barrier-free circulation, and environments designed to enhance visibility. This design exemplifies a Primary Prevention strategy, effectively addressing the causes of fall risks and genuinely considering the diverse physical limitations present in the Thai elderly population. To bolster residential safety, the researcher suggests incorporating additional safety technologies. Automatic path-lighting systems, which connect the bedroom and bathroom, are recommended to improve safety in low-visibility conditions, such as nighttime. Furthermore, emergency alert buttons should be positioned within easy access from the floor. This ensures individuals have a way to call for help if they fall or encounter other problems. Ultimately, it's crucial to improve residents' understanding of architectural safety. This ensures that safety equipment is used correctly and helps maintain a

safe indoor environment. As a result, this supports the development of lasting and sustainable safety practices. This study has several limitations that should be acknowledged: (1) analysis is based on architectural plan documentation only physical site inspection was not conducted; (2) the checklist covers two boundary-case unit types; intermediate types were not assessed; (3) the physical limitation data is nationally aggregated and cross-sectional direct sampling of Rama-Thanarak residents was not possible; (4) the study does not assess behavioral, social, or economic dimensions of aging-in-place outcomes. Future research should include post-occupancy evaluation with actual residents to validate plan-based findings, and expand coverage to additional international standards.

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