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Socio-Economic Constraints of Home Modification to Mitigate the Risk of Falls among the Elderly in the Diverse Regions of Thailand

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Abstract

This research highlights the inequality arising from socio-economic constraints in implementing home modifications to mitigate fall risks among the elderly. The study provides significant evidence of the complex association between low socio-economic status (SES) and its limitations in adopting fall prevention strategies, particularly in rural areas such as northern and northeastern Thailand. The SES related to home modifications for mitigating fall risks among the elderly was assessed through the three factors of house conditions, styles, and amenities. Houses in rural and urban areas were compared to highlight disparities in fall risk and the capacity to implement modifications. This research shows that fall risk in rural areas was significantly higher than in urban areas ($p = 0.03$), and SES in rural areas such as the north and the northeast was significantly lower than in more urbanised areas ($p < 0.00$). Furthermore, all three SES factors show a significant relationship with the incidence of falls ($p < 0.00$). Home modification construction cost can be categorised into three levels based on cost and scope: minor (24,000 Baht or 750 USD in 2021), moderate (30,500 Baht or 953 USD in 2021), and major (47,000 Baht or 1,469 USD in 2021). Major modifications as part of the research project covering structural renovations included reinforcement and replacement which accounted for 41% of the total construction cost, while costs for universal design equipment constituted 34% of the total construction cost. A key contribution of this study is the identification and quantification of specific socio-economic constraints that limit home modifications in rural areas of Thailand. The most significant constraints include financial limitations, poor housing conditions, and limited access to technical knowledge for modifying specific local housing conditions and styles. This research frames these constraints as critical barriers to achieving safe living environments for the elderly, particularly before universal design can even be applied. By offering a classification of home modification needs linked to socio-economic capacity and advocating for an increase in current government construction subsidies, —including labour costs—by at least 10%, the study provides a practical framework for assessing readiness and challenges in real-world aging in place settings.

Keywords

Home modification; Socio-economic status; Fall risk; Elderly; Aging in place policies

1. Introduction

Previous studies have suggested that environmental modifications can reduce fall risks for the elderly (Gill et al., 2000; Rand et al., 2011). One of the influential factors in mitigating risk is financial limitation for home modification. In the Thai context, research suggests that socio-economic factors also may play a significant role. Socio-economic constraints refer not only to financial limitations but also to limited awareness of fall risks and lack of technical guidance on home modification, particularly in housing with unique local styles. These factors particularly affect elderly populations in rural communities, where the gap between need and feasibility is most pronounced.

The socio-economic status (SES) of the elderly, including educational level, family income, and quality of life, can influence the risk of falls (Zhao et al., 2019). A higher incidence of falls is associated with lower socio-economic status among elderly living in poverty in India (Joseph et al., 2019). Socio-economic inequity limits fall risk mitigation due to lack of resources and support in the rural area. Even the inclusive design for a public park in the Bangkok Metropolitan Region had limitations on fall risk design implementation due to the SES of the municipality (Selanon et al., 2022). Fall risk factors associated with socio-economic determinants, including poverty, were observed among the low-income elderly living in rural Thailand (Iamtrakul et al., 2021). Socio-economic characteristics also were related to the fear of falling. Korean researchers found that the elderly living in rural areas who had lower SES had higher scores for fear of falling (Cho et al., 2013). Health conditions and financial independence can dramatically impact the elderly's quality of life (Shin et al., 2008) and quality of life consistently is found to be lower among elderly in rural than urban areas (Hongthong et al., 2015).

Financial insecurity could be a major constraint to home modifications, as budgets for health and access facilities are prioritized over those for home modifications (Iamtrakul & Chayphong, 2021). The cost of home modification for elderly in rural areas of Thailand has been reported as 20,000–25,000 Baht (567–709 USD in 2016) for minor renovations and 40,000–45,000 Baht (1,134–1,275 USD in 2016) for moderate renovations (ThaiHealth resource Center, 2016). Financial limitation also contributes to the focus on structure stability adjustment as the utmost safety factor rather than universal design standard adjustment (Sabatini et al., 2016).

The concept of ageing in place assumes paramount significance in promoting the well-being of older adults within their dwellings. To enhance the safety of living environments, the implementation of universal designs or direct guidance for a safe environment is imperative. The living environment is significantly associated with falls among older adults (Hongthong et al., 2015). However, only 1.4% of homes in Thailand were modified for the elderly was reported between 2017-2020[1], with most of these being located in urban areas like Bangkok and the southern region, while only 18% of modified homes were in the north (Aekplakorn, 2014). This disparity reflects not only income gaps but also unequal distribution of resources, information, and implementation support. Socio-economic characteristics can impact housing renewal from the individual home to the city scale (Shahraki, 2022). Few studies have systematically explored how these characteristics operate as constraints—particularly how they shape awareness, decision-making, and access to home modification.

House conditions are somewhat related to the SES of the occupants and can present hazards to the elderly. Poorer house conditions indicate higher fall risks among lower income elderly people in rural Indian communities (Joseph et al., 2019). Conditions such as structure stability and hygienic environment contribute to safety for the elderly. Unstable structures commonly found in rural areas expose the elderly to danger. Bathroom wall collapse resulted in the deaths of two elderly people in Thailand in 2025 (Khaosod Online, 2025)

House amenities also can facilitate safe environments. The main hazards associated with unsafe conditions include soil pathways, slippery floors, and non-asphalt walkways, such as gravel or red earth (Cho et al., 2013; Rongmuang et al., 2016). Furthermore, it is a challenge for the elderly to use a squat or semi-squat toilet due to their deteriorating muscle strength (Krishnan, 2019). Toilet-related injuries, primarily from toilet seats causing crush injuries, frequently have been reported in emergency rooms (Glass et al., 2013). Additionally, non-flush toilet users, predominantly in rural settings, face nearly double the toileting difficulties of their flush toilet-using counterparts (Fong & Feng, 2021). The prevalence of low-cost, low-maintenance squat or non-flush toilets necessitates targeted home modifications to reduce fall risks among the elderly, given constrained economic and social resources (Jakimovski, 2010).

This research aims to investigate the factors affecting fall risk mitigation strategies among the elderly in Thailand, focusing on differences across five regions and comparing rural and urban areas for analysis. House conditions, styles, and amenities are examined as both outcome and mediating factors representing SES, with urban-rural comparisons conducted. Guided by an integrative research framework, this study draws upon the Theory of Planned Behaviour to illuminate how individual attitudes and perceived behavioural control influence the willingness to invest in home modifications (Laheri et al., 2024). The Socio-Ecological Model is applied to capture the multi-level influences of family, community, and policy contexts that further enable or constrain these decisions. Furthermore, perspectives from Consumer Behaviour and Environmental Valuation theories are incorporated to examine how cost-benefit considerations and the subjective valuation of home safety affect the actual implementation of modifications. By identifying constraint-driven barriers and regional disparities, this study aspires to inform the development of more context-sensitive models and practical recommendations for ageing in place policy and home design across diverse Thai regions.

2. Literature Review

2.1 Behaviour and Social Theories

Understanding and addressing the barriers to home modification for fall risk mitigation in the elderly requires a multidimensional theoretical framework. The Theory of Planned Behaviour (TPB) (Ajzen, 1991; Laheri et al., 2024) informs this research by explaining how elderly individuals' intentions to make home adaptations for safety are shaped by attitudes, perceived social pressures, and perceived control over the process. However, personal motivation alone cannot overcome structural constraints, especially those related to socio-economic status (SES) and access to resources.

The Socio-Ecological Model (SEM) (Stokols, 1996) expands the study framework by situating fall risk mitigation behaviours within interconnected layers of influence—ranging from individual characteristics and household environments to community dynamics and policy contexts (Karlin, 2023). SEM helps to explain why similar interventions may yield different outcomes across rural and urban communities and among regions with differing economic and cultural backgrounds.

Consumer Behaviour Theory (CBT) further enriches this investigation by elucidating the decision-making processes underlying investments in home safety, highlighting how perceived value, cost-benefit considerations, and risk perception affect willingness to modify living environments (Schoberer et al., 2016). Likewise, Environmental Vulnerable Theory (EVT) contextualizes these decisions within a broader framework of how individuals and communities value health, safety, and quality of life improvements, especially as they relate to home conditions and amenities (Cutter et al., 2003). Even families in developed countries can face challenges

to undertaking home modification for various reasons including financial capacity and priority. Ranges of home modification include aging assisted equipment as part of the home renovation (Kim & Kim, 2023) .

Together, these theories provide a framework to characterize the complex interactions among individual beliefs, social and economic constraints, and environmental factors that not only influence fall risk mitigation strategies but also moderate the effectiveness of policy and design interventions for ageing in place across Thailand's diverse regions.

2.2 Socio-Economic Factors related to the Elderly

The social and economic needs of the elderly (Nanthamongkolchai, 2021) can be categorized into two main domains: social engagement and economic security. Regarding social engagement, older adults require attention and care from others. This includes being recognized as integral members of their families, communities, and various social groups. Furthermore, they benefit from the opportunities to assume social roles that correspond to their abilities and to participate actively in community and social activities.

In terms of economic needs, older adults often require support or assistance from both their families and society. This includes support related to living conditions, income maintenance, and access to government services. Importantly, the provision of such assistance should aim to reduce dependency while ensuring income security and affirming welfare benefits for the elderly (Nanthamongkolchai, 2021).

Socio-economic factors related to the elderly's environment also include income level, house ownership, house appearance as a symbol of social status within the community, and quality of living (Knurowski et al., 2005). Socio-economic inequality is associated with poor health and well-being conditions, particularly among the rural elderly (Zhao et al., 2019; Iamtrakul et al., 2021).

2.3 Fall Risk related Environment Factors

Environmental conditions can elevate fall risk. With physiological deterioration, the same environmental conditions may challenge the elderly and increase their fall risk. The majority of elderly emergency incidents in 2021 involved falls on level floors (66%) and falls within the house (31%) (National Emergency Medical Institute, 2019). The bathroom environment is widely recognized among scholars as presenting the highest fall risk, with wet floors, toilet model, and unstable handrails as key hazards (Gell et al., 2020; Keall et al., 2021; Ng et al., 2021; Chindapol & Arkarapotiwong, 2023; Hussain et al., 2023; Nimmol et al., 2025). Environmental risks may be studied based on house conditions and house amenities.

House conditions include home ownership, structure stability, and environmental hazards (Gill et al., 2000). Home ownership strongly affects home modification for the elderly (Nitbongkoch, 1998). Studies in rural India and China have confirmed that elderly poor have limited financial support for house renovation, particularly with respect to structural reinforcement (Jakimovski, 2010; Yu et al., 2017).

The local Thai house style consists of elevated timber houses, which generally are found across Thailand, particularly in rural areas. However, they pose a higher fall risk due to steep staircases (Thiamwong et al., 2008). Certain elevated platform traditional house styles may cause higher risk. Despite the recognised safety advantages of single-storey residences for the elderly, 44% of this demographic in Thailand inhabits two-storey or elevated homes, with nearly half (49%) navigating stairs daily (Sirimuangmoon & Saicharoent, 2016). These homes, often featuring wooden structures with high stairs leading to remotely located outside bathrooms, are prevalent in rural areas, particularly in the northern mountains and northeastern fields. In the central plain region, 30% of residences maintain this elevated architecture, contributing significantly to the heightened risk

of falls among the elderly (National Emergency Medical Institute, 2019). Physical environmental factors further intensify fall risks, not only in relation to the poorer physical environments, but also poorer awareness and greater cultural limitation (Chindapol & Arkarapotiwong, 2023). Sleeping on the floor or locating the bathroom outside the house are some risk characteristics related to fall in Thai traditional local houses (Chindapol, 2025). Taiwanese scholars found that approximately 30–60% of falls take place among older adults who live in rural communities (Cheng & Chang, 2017). Similar to the research findings in India, elderly in rural Thai households are at higher risk of falls than those in urban households owing to lower standards of housing and limited accessibility to health services (Chacko et al., 2017). A study in rural upper north Thailand showed that the 462 ethnic elderly people who had fallen in the previous year had a lower quality of life and awareness than those who had not fallen (Kantow et al., 2021).

Houses that include amenities related to elderly assistance generally have lower fall occurrence. Seated toilets are the most basic amenity for bathroom safety, while squat toilets present the most frequently reported risk hazard in the bathroom (Jakimovski, 2010). Handrails and elderly aid amenities not only can reduce fall risk but also improve living quality and safety (Keall et al., 2021). While falls commonly are found in the elderly demographic, the greatest frequency occurs in the bathroom (Sze et al., 2001). Bed height, when appropriately matched to the elderly's body size, can reduce falls (Morris et al., 2022).

Fall risk can be quickly screened using six factors: gender, visual impairment, walking balance, daily medicines, fall history, and living on an elevated platform (Thiamwong et al., 2008). Additional health factors including age, fall-related non-communicable diseases such as hypertension, diabetes, and gout, and mental status also increase fall risk. However, health conditions are not covered in this study since they are not the main objective and have been clearly addressed in other research (Kim & Park, 2000; Clemson et al., 2008; Chindapol & Arkarapotiwong, 2023).

A notable research gap remains in understanding how socio-economic status (SES) differences specifically impact the ability of low-income elderly individuals to implement home safety modifications. While several studies have focused on financial limitations of the low-income home modifications (Mathieson et al., 2002; Iamtrakul et al., 2021), less attention has been given to the challenges posed by local house conditions and styles, which present significant obstacles to modification. Additionally, low-income elderly individuals often lack access to construction knowledge due to their low education levels and limited awareness of fall risks (Lin et al., 2017). While previous studies acknowledge the importance of SES (Cho et al., 2013), there remains limited investigation into the complex relationship between socio-economic constraints, housing characteristics, and fall risk mitigation strategies, particularly in the elderly population of Thailand. Although intrinsic factors, socio-cultural dimensions, and body size differences across sub-ethnicities (Chindapol, 2025) are reported to influence fall risk mitigation and home modification, they are not covered in this research due to their weak connection to the socio-economic domain.

3. Methods

This research is an extension of the project conducted in 2021 (Chindapol & Arkarapotiwong, 2023), and aims to validate the assumption that the SES is involved differently in falls among Thai elderly. During the project, economic and social status were observed, leading to the research question: How do the economic and social status of low-income elderly individuals affect home modifications differently across five areas? The research methods are in three parts: fall risk screening, home modification, and constraint investigation.

3.1 Study Area

Thai elderly in high senior population communities were targeted across five regions in Thailand: the north, northeast, central, south and suburban Bangkok. These regions were represented by Chiang Mai (north), Khon Kaen (northeast), Pathum Thani (central region), Bangkok (sub-urban capital area), and Songkhla (south). The selection of representative communities followed three main criteria:

- The community is officially recognized as a low-income area.
- There is ongoing and significant contribution to elderly services and activities.
- Each community was scored against five candidates in their respective region, with the highest-scoring area chosen as the representative for that region.

Within each selected community, fall risk screening was conducted in 2021-2022 using a purposive and participatory sampling procedure. Community leaders nominated elderly residents based on specific criteria: being aged 60 and over, low monthly income (less than 3,000 Baht or 94 USD in 2021), active involvement in community activities, and residing in homes deemed unsuitable or unsafe for elderly living. Preliminary scoring was conducted to prioritize candidates, and at least 40 elderly participants were selected per community, resulting in a total sample of 202 participants.

Peri-urban households were defined as those located at the transitional fringes of the urban core, neither strictly urban nor rural, and were identified according to administrative boundaries and local development patterns in each regional context. The urbanisation of the community was classified by population density: rural areas (< 1,000 people/km^2) and urban areas (> 1,000 people/km^2). Based on this classification, Chiang Mai (587 people/km^2) and Khon Kaen (789 people/km^2) were considered rural areas, while Rangsit (4,051 people/km^2), Bangkok (6,887 people/km^2), and Songkhla (1,050 people/km^2) were considered urban areas (D igital Government Development Agency (Public Organization) [DGA], 2022). The participatory approach and community-based sampling methods followed established procedures cited in previous research (Chindapol & Arkarapotiwong, 2023). Socio-economic status (SES) was evaluated, and the referendum method was used for final community agreement in the selection process. The fall risk screening included both personal health status and house conditions.

3.2 Survey methods

Home modification of the bathroom was prioritised. The fall risk from the physical environment was assessed in 202 houses. The physical environment in all 202 homes was assessed for fall risk factors. To analyse socio-economic constraints and priorities for home modification, SES data were obtained for all 40 elderly participants per community. After comprehensive assessment (including a health check, fall-risk screening, and detailed home environment survey), the combined risk scores for health and environment were used to rank participants in each community. Only the top 20 homes with the highest fall risk scores in each community were selected for actual home modification interventions, rather than design-only solutions. These interventions were categorised into three levels: minor modifications (e.g., installation of handrails and improved lighting), medium-scale adjustments (e.g., small ramp construction and door replacement), and major renovations (e.g., building a new bathroom). The selected homes were further analysed for SES score and construction costs.

The construction process took 2–6 months in each community, depending on the COVID-19 situation and on-site complications such as limited accessibility and the contractor's construction management. The ethic declaration was approved with anonymous data publication, ethic ID: CMUREC63/271. Constraints were

identified throughout the study. Revisits with semi-structured interviews were conducted three months after modification. Focus group meetings during the modification process further identified constraints. This research focused on SES and fall risk mitigation through home modification. Figure 1 shows the research and sample collection methodology.

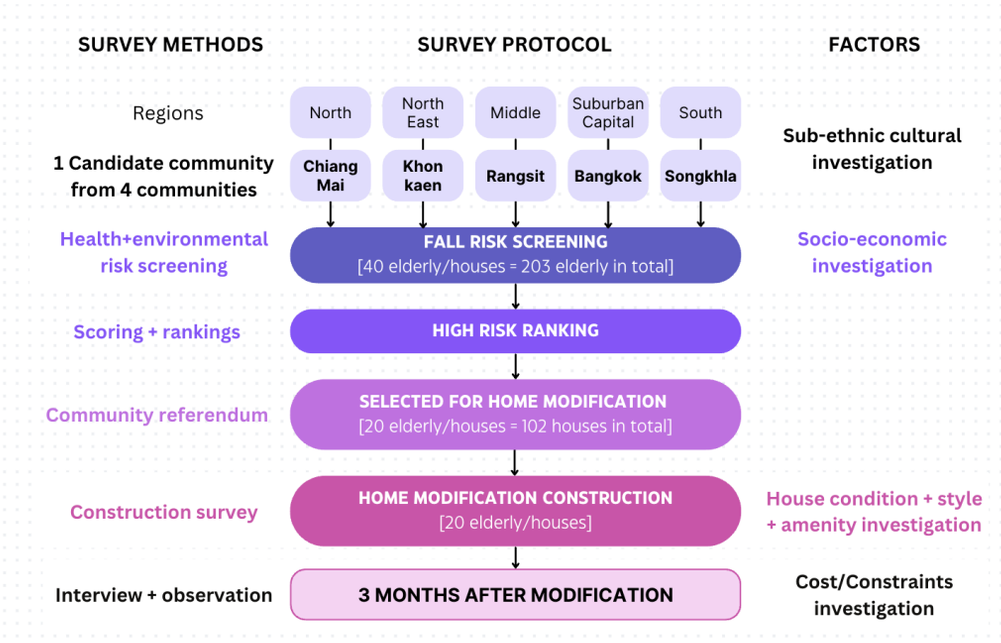


Figure 1. Research methodology and sample.

The socio-economic constraints are categorised into three overarching domains: house conditions, styles, and amenities. Financial limitations were reflected in budget-oriented home modifications and limited amenities. House conditions represent quality of life as a reflection of social well-being and covered six aspects: lack of house and land ownership, demolishment conditions, lack of budget for home modifications, structural instability, inappropriate functional planning, and unhygienic living conditions. Each aspect scored 1 point except structure instability scored 3 points since it brings the utmost and sudden hazards to the elderly. Higher scores denoted higher constraints (Sabatini et al., 2016). All these conditions were assessed using a nominal scale with yes-no questions, except for inappropriate functional planning and unhygienic living conditions, which were evaluated by the researcher based on fundamental living standard criteria, including the presence of a proper sleeping area and a toilet with wall and roof coverings. The scores were then combined to generate overall house condition scores for each region, which were averaged for urban-rural comparisons. A higher score indicates a lower socio-economic status.

House style represents social status within the community. House style was categorised and scored based on bathroom location, house elevation, and structural materials. A bathroom located outside the house, which presents a fall hazard at night, scored 3 points, while an elevated house, posing hazards throughout the day, scored 5 points due to its higher level of constraint (Ong et al., 2022). Structural materials were ranked by modification difficulties as follows: shelter (3 points), timber structure house (2 points), half-timber half-cement house (1 point), and cement house (0 points). However, information regarding the ages of houses was not collected, which may have influenced the house style.

House amenities reflect the economic status of the family and include living amenities such as a TV, refrigerator, washing machine, bed, floor tiles, air conditioner, and squatter toilet. Each domain was scored for each house and averaged separately to represent a regional score. Each amenity was assigned 1 point per house, with higher scores reflecting richer amenities and lower constraints. This scoring direction differs from that of house condition and house style, where higher scores indicate greater hazards or constraints. The distinction was maintained intentionally to reflect the conceptual meaning of each domain, although it requires careful interpretation when comparing across categories. Construction costs related to the degree of home modification also are discussed in this paper.

The overall SES scores ranged from -19 to +7 points, based on negative scores from house conditions (up to -8 points) and house styles (up to -11 points), combined with positive scores from house amenities (up to +7 points). A mixed method approach was used for the analysis. Qualitative methods based on house characteristics were employed for constraint investigation before, during, and after construction. Since the data were not normally distributed, the Kruskal-Wallis H-test and Mann-Whitney U-test were used for statistical analysis. The Wilcoxon Signed-Rank test was applied to examine the relationship between falls and socio-economic status, as these were related samples. Findings on these relationships are presented in the discussion. IBM SPSS statistics software version 29.0 was used for data analysis.

4. Results

4.1 Socio-Economic Status Constraint of the Elderly Home Modifications

A lower socio-economic status correlates with greater limitations in home modification. Socio-economic status is represented by indicators related to house conditions, house style, and house amenities. Higher scores in house conditions and house style indicate lower socio-economic status, while higher scores in house amenities reflect a higher economic status of the household. The percentages represent the proportion of houses within each region. The northern region had the poorest house condition scores, whereas the northeastern region showed the worst outcomes in both house style and amenity scores. The suburban capital area showed the best overall status due to the low risk of house conditions and house style, with the highest house amenities. Importantly, most elderly households in all settings reported having no budget for home modification and insecurity of house or land ownership was common in certain regions. These specific barriers further limit opportunities for safe ageing in place, particularly among households with lower socio-economic status. The results for all conditions are detailed in Table 1.

Table 1. Socio-economic status results of the elderly in five regions of Thailand

Region [sample] / Socio-economic factors	North [n=41]	Northeast [n=40]	Central [n=41]	Sub-urban capital [n=40]	South [n=40]
House conditions (mean score)	**7.05**	**6.25**	**5.59**	**5.65**	**5.90**
SD	**3.16**	**2.96**	**3.57**	**3.51**	**2.81**
No house and land ownership (1 point)	5%	0%	32%	13%	0%
Under demolishment condition (1 point)	5%	0%	5%	15%	0%
No budget for home modification (1 point)	98%	100%	93%	73%	70%
Instability of structure (3 point)	37%	33%	32%	30%	18%
Inappropriate functional planning (1 point)	68%	53%	54%	58%	65%
Unhygienic living condition (1 point)	61%	45%	32%	43%	60%
House style (mean score)	**4.49**	**6.45**	**5.39**	**2.75**	**4.05**
SD	**0.99**	**0.73**	**1.02**	**0.80**	**0.92**
Bathroom outside the house (3 points)	73%	63%	15%	18%	15%
Elevated house (5 points)	27%	75%	80%	33%	58%
House material style (average 0-3 points)	2.17	2.10	2.20	2.40	2.28
Shelter (3 points)	7%	5%	12%	3%	8%
Timber (2 points)	20%	8%	7%	13%	10%
Half-timber half-cement (1 points)	22%	60%	29%	28%	30%
Cement (0 points)	51%	28%	51%	58%	53%
House amenities (mean score)	**2.56**	**2.25**	**3.37**	**3.65**	**3.43**
SD	**1.38**	**1.44**	**2.21**	**1.94**	**2.06**
Maximum amenities score in each house	6 (n=2)	5 (n=4)	7 (n=3)	7 (n=3)	7 (n=1)
Minimum amenities score	0 (n=2)	0 (n=6)	0 (n=6)	0 (n=1)	0 (n=2)
Houses with amenities					
TV (1 point)	59%	63%	71%	63%	58%
Refrigerator (1 point)	54%	58%	73%	80%	73%
Washing machine (1 point)	32%	35%	49%	60%	55%
Bed (1 point)	80%	43%	51%	55%	73%
Floor tiles (living or toilet areas) (1 point)	27%	18%	39%	68%	48%
Air-conditioner (1 point)	0%	0%	15%	15%	5%
Squatter toilet (1 point)	5%	10%	39%	25%	33%

4.1.1 House conditions

House conditions can reflect quality of life and overall well-being. Property ownership, demolishing conditions, and the lack of a renovation budget are linked to the socio-economic status of the household, while structural instability affects functional planning and hygienic conditions. In rural Thailand, structural instability in houses commonly is observed in low-income villages, as these structures often are built as inexpensively as possible to align with the residents' economic constraints. All areas seem to have limited

resources for house construction and maintenance, with high house condition risk scores (5.59–7.05 points in Table 1). This may be due to the similarly low-income elderly selection criteria used for this research. Interestingly, although the central region shows the lowest risk in house conditions with 5.59 points, the highest standard deviation also is observed. This can be interpreted as the greatest variability in house conditions among all areas. Comparing the northern and the central regions, the number of houses with the poorest house conditions is similar at about 10 houses, while the best conditions are much different. Only seven houses, 17%, in the north show low-risk house condition scores (<4 points), while 17 houses, or 41% of the central region, show this low risk.

The primary obstacle to effective modification plans lies in the structural instability of residences, where the associated construction and modification costs may surpass those allocated to specific needs of the elderly. Most houses in the northern, northeastern, and central regions lacked a budget for home modifications (>90%). Houses in the north exhibited more structural instability than those in other regions, with 15 houses (37%) affected, followed by the northeast with 13 houses (33%). The southern region had the lowest number of structurally unstable houses, with only 7 houses (18%) (Table 1). Among these, six houses in rural areas of the north and northeast failed to meet the standard of living and required new structural construction. Some of these houses had bathroom structures without columns, detached walls, and unfinished roofs. Major renovations were necessary to bring these houses up to standard before addressing fall risk reduction (Figure 2). Many residences occupied by elderly individuals initially were constructed as basic shelters or incomplete structures that lacked standardised architectural integrity. These structures exhibited deficiencies such as incomplete walls, half-height walls made with fabric or fibreboard to enclose openings, the absence of window frames, and unstable bathroom structures that featured stained zinc sheets for roofing and walls. In certain instances, the bathroom was located outside the main dwelling and had inadequate roofing. The timber frame structures utilised in some bathrooms lacked the requisite strength for secure handrail installation. Such residences posed considerable risks to the safety and well-being of their elderly occupants. Given the high potential for personal health hazards and increased risk of falls in these homes, there is a compelling recommendation for urgent home modifications, irrespective of the underlying structural instability.

Structural instability may be a dominate constraint factor for home modification when considering lack of budget and other complications of structure for renovation. This study advances two distinct modification concepts tailored to residences with unstable structures: structural reinforcement; or replacement with a new structure. To provide a financially feasible solution with substantiated efficacy for the elderly, the initial approach involved the implementation of a cost-effective strategy utilizing small steel frames and timber beams, predominantly installed to reinforce handrails or inclined pathways, totalling 22 houses. The second concept entailed a comprehensive replacement of unsound structures, targeting residences necessitating moderate to major modifications, totalling 2 houses. This involved the substitution of columns and beams for roofing and wall structures with lightweight lip-channel carbon steel and rectangular or square steel tubes. In addition, existing walls were replaced with cost-effective alternatives, such as cement blocks, which are commonly utilised for fencing. In such cases, approximately half of the overall home modification cost was attributed to the structural replacement component.

(a) (b)

Figure 2. Structural instability before modification in the north: (a) bathroom without a roof and wall; and (b) a bathroom shelter with temporary walls and no door or roof. (source: photos by author, 20 Jan 2021)

4.1.2 House style

House style can reflect social status. A house constructed with cement is considered to represent higher social status compared to those built with timber or shelter structures. Features such as an outside bathroom and an elevated house, while conventional, are considered outdated and inconvenient, indicating a higher risk of falls and a lower social status in middle- to low-income communities. In the northeastern region, most houses were of a half-timber, half-cement structure (60%), whereas in suburban areas near the capital, the majority of houses had a cement structure (58%).

These differences in house style are rooted in local cultural traditions, environmental adaptations, and economic contexts unique to each region. Another interpretation is that majority of houses in areas outside the capital still use traditional house styles, unlike those in more urbanised areas like the suburban capital, with house style risk scores above 4 points as shown in Table 1. The prevalence of exterior bathrooms in rural areas poses an elevated fall risk for the elderly, particularly during nighttime visits. The traditional housing practices in northern and northeastern Thailand often involve situating toilet facilities in a separate shelter outside the main dwelling to segregate sanitary functions from living areas (Figure 3). Only 15% of bathrooms in urban areas are outside the house, whereas most bathrooms in rural areas (the north and the northeast) are outside the house. This pattern reflects both economic status and longstanding local customs. This is related to the economic status of the elderly in rural areas. Although commode chairs may be utilised in the bedroom, predominantly for urination, elderly individuals face heightened fall risks when traversing to external bathroom shelters, particularly during nocturnal hours. A research interview underscored the challenges faced by elderly individuals with diarrhoea, who necessitate multiple nighttime visits to the external toilet shelter. In cases where constructing an internal toilet is financially constrained, the implementation of strategic modifications is advised, encompassing enhancements such as improved lighting, pathway modifications, installation of handrails along walkways and within the toilet zone, and the use of rough-surfaced flooring materials to mitigate fall risks (Figure 4).

Houses in the northeastern and central regions more commonly featured a conventional elevated style compared to other regions. Over three-fourths of the houses in these areas followed this elevated design (Table 1). The preference for elevated houses in these regions is shaped by both cultural tradition and practical considerations, such as flood prevention. Although the material style of the houses was similar, the northeastern region exhibited the worst socio-economic status among all regions, with an average score of 6.45 points, compared to 5.39 points in the central region, which had the second-lowest socio-economic status.

(a) (b) (c)

Figure 3. Bathroom shelters outside the house before modifications: (a) House A in the north; (b) House B in the north; and (c) House C in the northeast. (source: photos by author, 20 Jan and 12 Feb 2021)

(a) (b) (c)

Figure 4. Bathroom shelters outside the house after modifications: (a) House A in the north; (b) House B in the north; and (c) House C in the northeast. (source: photos by author, 13 Mar 2021 and 25 Aug 2022)

4.1.3 House amenities

The number of amenities in a house reflects its socio-economic status and can assist with convenience and fall reduction for the elderly. For instance, houses with floor tiles, installed air conditioners, a laundry machine, refrigerator, and a bed with a mattress are considered to have high socio-economic status within the community. Urbanisation may encourage the elderly to acquire amenities for their houses, with Table 1 showing higher amenities in more urbanised areas. Suburban areas near the capital and the central regions had the highest number of amenities, with average scores of 3.65 and 3.37 points, respectively, and three houses featured the maximum number of amenities (Table 1). In contrast, the northeastern region had the lowest amenities score, with an average of 2.25 points. Squatter toilets are another constraint of modification. Most toilets (95%) in rural areas (the north and the northeast) are squatter toilets, whereas only 69% of toilets in urban areas are squatter toilets. When the elderly are in a squat posture while using the toilet, they are at a higher risk of falling, particularly due to losing their balance before and after using the toilet. Some elderly apply a timber sheet to the squatter toilet to sit on. Other elderly people have a seated toilet installed over the squatter one, causing them to make a higher step to access the toilet, as the new toilet is now more elevated. The squatter toilet should be replaced by a seated toilet at the bathroom floor level. Some seated toilets were installed over the sanitary tank, which led to fall risks from an over-elevated seated toilet (Figure 5). Some bathrooms needed repair or building of the sanitary system. Handrails next to the toilet must

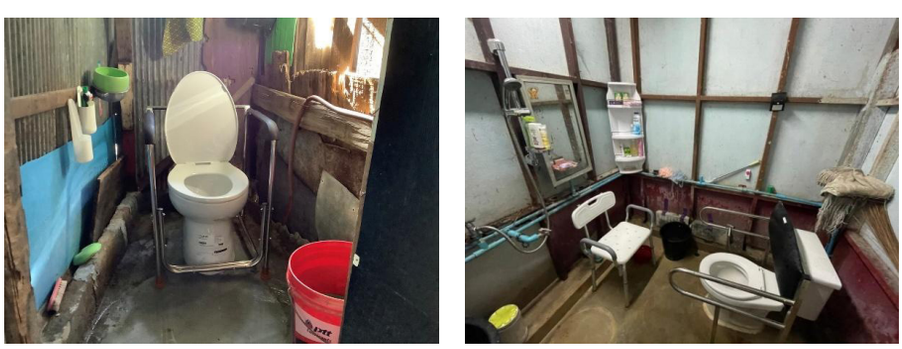
be installed on both the toilet and bath areas. Toilet handrail installation might be an issue if the seated toilet is not the original toilet in the bathroom. The toilet may be installed in the middle of a room with no walls for handrail installation. The handrails should only be installed from the floor; otherwise, they may not have sufficient structural integrity. Researchers in the central region and the south invented a handrail set covering the seated toilet for stability. In addition to addressing the insufficient structural integrity of bathroom walls by installing sufficiently robust grab bars, this intervention also served to remediate issues related to the absence of walls or suitable surfaces for the installation of grab bars adjacent to toilet fixtures (Figure 6).

In rural areas, the preference for using a bath and tank as opposed to a shower is attributed to potential limitations in the strength and stability of the water supply system. Standing during bathing poses an increased risk of falls for the elderly, as the need for rapid head movements combined with wet and slippery conditions heightens the likelihood of accidents. To mitigate this risk, the use of a bath chair and the installation of handrails in the bathing area are highly recommended for the elderly (Figure 7).

A mattress without a bed for sleeping can lead to fall risks due to its low level. Most elderly in this research used mattresses on the floor without a bed, most of whom were from the northeast (57%), followed by those from central region (49%), sub-urban capital (45%), the south (27%), and the north (20%). These might relate to the chilly weather in the north and south, compelling the elderly to use a bed to avoid humidity from the ground. A mattress and temporary quilt were used as a bed on the bedroom floor or multi-purpose area of the house. In Thailand, the multi-purpose area is used for living, dining, and sleeping, particularly in a house with many members and limited space.

(a) (b)

Figure 5. A seated toilet built over a squatter toilet before modification: (a) in the north; and (b) in the south. (source: photos by author, 30 Mar 2021)



(a) (b)

Figure 6. Handrail set covering the seated toilet: (a) the seated toilet with the handrail structure set placed on the evened floor in the south; and (b) a handrail set with a backrest in the central region house. (source: photos by researchers, 23 Dec 2022 from Arkarapotiwong, et al., (2022))

(a) (b)

Figure 7. Water tank for bathing placed next to the toilet in the northeast house: (a) before; and (b) after modification. (source: photos by researchers, 25 Nov 2022 from Arkarapotiwong, et al., (2022))

Figure 8. A quilt and mattress used as a bed on the floor in houses in the northeast. (source: photos by researchers, 18 Oct 2021 from Arkarapotiwong, et al., (2022))

4.2 Differences of Socio-Economic Status between Study Regions and Housing Characteristics

Considering house conditions as a representation of socio-economic status, rural areas exhibited poorer overall conditions compared to urban areas as defined in the Methods section. Pathum Thani (Rangsit), although sometimes perceived as peri-urban due to its transitional context, was classified as urban in this study according to the applied criteria. The northern region had the highest mean score for house conditions (7.05 points), while the central region had the lowest score (5.59 points). The northeastern region recorded the highest score for house styles (6.45 points), whereas the suburban capital area had the lowest score (2.75 points). Conversely, the northeastern region had the lowest score for house amenities (2.25 points), while the suburban capital area had the highest score (3.65 points). A divergent trend appears when comparing house condition and house style scores with house amenities. Figure 9 further illustrates that the trend lines for house style scores and total falls are similar. The overall incidence of falls among the elderly was 21.7%, with the northeastern region accounting for the highest number of falls (12 falls, 30%), followed by the southern (11 falls, 27.5%) and northern regions (10 falls, 24.4%).

In the comparison of house amenities between the rural and urban areas, no air conditioner was used in the houses in the north and the northeast. By contrast, the highest numbers of houses with a TV set, a refrigerator, and an air conditioner were found in the central region and sub-urban capital (Figure 9). Houses in the rural areas showed significantly lower mean scores (shown in Table 3) for house amenities than those in the urban areas (2.56 and 2.25 vs 3.37, 3.65 and 3.43).

These regional differences are influenced by distinctive local cultures, traditional construction practices, and varying levels of access to public services. For instance, rural areas often maintain traditional house styles and external bathrooms due to long-standing cultural preferences and geographic context, whereas urban and suburban areas have shifted towards modern styles and better in-house amenities owing to higher economic status and easier access to housing improvement services. Such disparities highlight the importance of tailoring local policies and interventions to address not only economic constraints but also cultural and service delivery realities in each region.

To test differences in socio-economic status among five regions, house conditions did not show significant variations, with $p>0.05$. Detailed analysis revealed significant differences in house styles between six pairs (Table 2), with $p<0.05$. The highest house style scores were recorded in the northeast, followed by the north, central region, suburban capital, and the south. Regarding house amenities, significant differences were observed in only four pairs. The lowest amenity scores were in the northeast and north, followed by the suburban capital, central region, and the south.

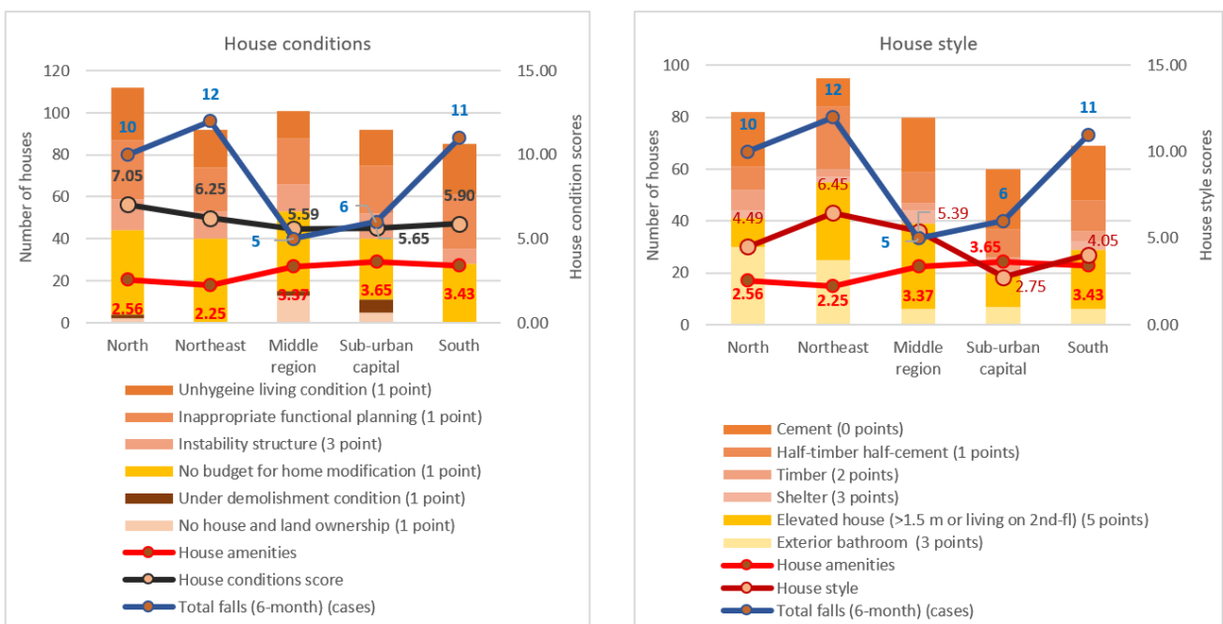


Figure 9. Chart depicting the house conditions (left) and house styles (right) representing socio-economic status in each study region.

Total falls show a strong significant relationship with socio-economic status. Compared to total 6-month falls, all three socio-economic status factors show a significant relationship with $p<0.01$. The number of falls in the rural areas was not only significantly higher than that in the urban areas ($p = 0.03$) (Table 3) but also was inversely proportionate with the mean scores for house conditions and styles (Figure 9).

The rural areas show lower socio-economic status and higher falls. House conditions, house styles and falls in the rural areas are higher than those in the urban areas, with $p = 0.02$, 0.00, and 0.03, respectively. Whereas house amenities in the rural areas are lower than those in the urban area with $p < 0.00$ (Table 3).

Table 2. Statistical analysis of the mean differences between house conditions, house styles, and house amenities for the study regions

Factors	Comparison	p	mean	Factors	Comparison	p	mean
Kruskul-Wallis							
H-Conditions	5 settings	0.121	-	-	-	-	-
H-Styles	5 settings	<0.001**	-	-	-	-	-
H-Amenity	5 settings	0.009**	-	-	-	-	-
Mann-Whitney							
H-Style	N < NE	0.023**	35.33<46.93	H-Amenity			
	N = NE	0.389					
	N = C	0.073			N = C	0.090	
	N > Sub-urban	0.030*	46.51>35.35		N < Sub-urban	0.013*	34.71<47.45
	N = S	0.653			N = S	0.093	
	NE > C	0.014*	47.40>34.76		NE < C	0.022*	35.03<46.83
	NE > Sub-urban	<0.001**	53.36>27.64		NE < Sub-urban	0.002**	32.60<48.40
	NE > S	<0.001**	49.40>31.60		NE < S	0.018*	34.43<46.58
	C > Sub-urban	<0.001**	51.26>30.49		C = Sub-urban	0.586	
	C = S	0.101			C = S	0.924	
	Sub-urban = S	0.068			Sub-urban = S	0.559	

Note: N denotes north, NE denotes northeast, C denotes Central region, Sub-urban demoted sub-urban capital, and S denotes south.

Table 3. Relationship of falls and house conditions, house styles, and house amenities in five settings, and the difference between rural and urban settings

Stat.	Factors	Settings	p	Mean
Wilcoxon Signed Rank	Falls & H-Conditions	5 settings	<0.001**	-
	Falls & H-Styles	5 settings	<0.001**	-
	Falls & H-Amenities	5 settings	<0.001**	-
Kruskul-Wallis	H-Conditions	Rural > Urban	0.022*	112>93
	H-Styles	Rural > Urban	0.003**	116>91
	H-Amenities	Rural < Urban	<0.001**	84<113
	Falls	Rural > Urban	0.032*	109>96

Note: p = significant level, *p < 0.05, ** p < 0.00

4.3 Construction Costs for the Elderly Home Modification

After home modification, construction costs and socio-economic status were investigated. The home modification cost for the elderly's houses that was averaged for 101 houses in the five study regions was grouped into three categories as follows: First, a minor modification without structural modifications would cost 24,000 Baht (or 750 USD in 2021), including construction materials and labour costs. Minor modifications

included handrails in the bathroom, entrance installation, and squatter toilet replacement. The labour cost for this minor modification was 3,000 Baht (or 94 USD in 2021) on average, or 12.5% of the total cost. Second, a moderate modification with structural reinforcements would cost 30,500 Baht (or 953 USD in 2021), including installations of a handrail and its structural support, an entrance ramp, sliding door replacement, lighting renovation, bathroom floor tile installation, and bedroom modification. Lastly, a major modification with new structural replacements would cost 47,000 Baht (or 1,469 USD in 2021) on average, including replacement of the main structure, roof sheet replacement, wall installation, a leaching cesspool and sanitary system, an entrance ramp, and a new bathroom building. The cost for the roof-wall structure and sanitary-related system was 59.95% of the total cost. The labour costs for the major modification were 12,885 ± 10% Baht, or 27.40% of the total cost. For the unstable structure in one of the north houses, a major modification was made. Construction of a new bathroom was required, and the reinforcement structure of the house was modified. The costs for the structure of the house and universal design equipment were 41% and 34% of the total construction cost, respectively.

Figure 10. Major modification in a house in the north: (a) before modification of the bathroom shelter and bedroom (source: photos by author, 20 Jan 2021); (b) after modification of the structure of the bathroom shelter and structural reinforcement of the wall of the house. (source: photos by author, 20 May 2022)

Home modification construction costs for the elderly and persons with disabilities can be subsidised by the local government, covering 22,500 and 40,000 Baht for structure modifications[2]. The costs are for both construction materials and labour expenses for flexibility in real-life situations, as each home requires different levels of modification and labour costs. In the previous protocol of the home modification implemented by local authorities, the government allocated only 3,000 Baht per house for labour costs, which was considered insufficient. In this project, the contractor received a total of 60,000 Baht for the labour costs across 20 houses in each area, which corresponds to an average of 3,000 Baht per house, consistent with the local authority's home modification guideline. The Provincial Social Development and Human Security, a local government agency, was responsible for allocating budget for these houses. However, the study results show that the budget was inadequate in real-life situations, particularly for major modifications. The findings emphasise a need for policy improvement to increase the budget allocation for home modification, as the actual costs consistently exceeded the current governmental support, especially for moderate and major modifications. The comparison between the minor modification costs revealed that the total construction cost was 1,500 Baht, or 6.7% higher than the government budget in real-life situations. For the moderate modification, the total construction cost was 7,000 Baht, or 17.5% higher than the government budget in the real-life situation,

similar to the labour cost. Despite the mean labour cost for all houses in this research being 3,687 Baht, the allocation recommended by the government was 3,000 Baht per house. The interventions ranged from minor adjustments, such as handrails and lighting, to major renovations, such as constructing new bathrooms, resulting in slight variations in labour costs across houses. The contractor's payment of 60,000 Baht for 20 houses was therefore generally aligned with the government guideline. This illustrates that the realistic labour cost was 22.9% higher than the cost expected by the government. Furthermore, the implementation revealed a shortage of local skilled workers and home modification specialists in many communities, suggesting that policy makers should consider supporting the development or training of local practitioners for sustainable and effective home modification services.

After home modification, some conditions in SES were different. Socio-economic status scores of 101 modified houses are shown in Table 4. Scores in house condition factors were lower and those in house styles remained unchanged, while those in house amenities were higher. House conditions and house styles scores provide a negative effect on socio-economic status, scoring negative points; while house amenities give a positive effect, scoring positive points. The lower the SES scores show, the greater the constraints a house would experience. The overall socio-economic status score of the northeast was the worst with -10.50 points, followed by the north with -9.34 points. After modification, the situation in the northeast was better but still remained the worst rank with -6.70 points. The maximum change after modification was the north, with a 5.10 point improvement. It is noted that there were no elderly falls within three months after modification for any modified house.

Table 4. Socio-economic scores for the 101 houses after modification

	H-Conditions (negative impact, points)			H-Styles (negative impact, points)			H-Amenities (positive impact, points)			Socio-economic status (SES score, points)		
	Before	**After**	**Diff**	**Before**	**After**	**Diff**	**Before**	**After**	**Diff**	**Before**	**After**	**Diff**
North	-7.60	-3.80	+3.80	-4.49	-4.49	0.00	+2.75	+4.05	+1.30	-9.34	-4.24	+5.10
Northeast	-6.30	-3.80	+2.50	-6.45	-6.45	0.00	+2.25	+3.55	+1.30	-10.50	-6.70	+3.80
Central	=5.45	-3.35	+2.10	-5.39	-5.39	0.00	+3.95	+5.15	+1.20	-6.89	-3.59	+3.30
Sub-urban	-7.55	-3.65	+4.00	-2.75	-2.75	0.00	+2.95	+3.95	+1.00	-7.35	-2.45	+4.90
South	-5.70	-3.00	+2.70	-4.05	-4.05	0.00	+3.85	+5.15	+1.30	-5.90	-1.90	+4.00

5. Discussion

5.1 Socio-Economic Status Differences among Five Regions

The assumption of socio-economic status differences among five regions was confirmed. Considering three socio-economic status factors, the northeast exhibited a significantly lower SES status leading to the highest fall risk among all five regions. This region also had the poorest house styles and amenities, with limited resources and technical construction support for modifications. This is confirmed by several studies in urban (Selanon et al., 2022) and rural areas (Iamtrakul et al., 2021) in Thailand, and in India (Joseph et al., 2019). However, a different perspective discussed with the participants revealed that the elderly in the north faced higher risks than those in the northeast when focusing primarily on environment fall risks (Chindapol, 2025). Therefore, it is crucial not to overlook socio-economic status of the elderly, alongside their health and environmental fall risks, when planning home modification.

These findings align with the Social Ecological Model (SEM) and Environmental Vulnerability Theory (EVT), emphasizing that both individual and environmental factors affect fall risk and modification outcomes (Wang et al., 2025). Additionally, aspects of Theory of Planned Behaviour (TPB) and Consumer Behaviour Theory (CBT) (Schoberer et al., 2016) highlight the influence of local attitudes, subjective norms, and perceived behavioural control, as well as personal preferences and choice patterns, on the acceptance and success of home modification interventions (Kim & Kim, 2023 ; Laheri et al., 2024).

Fall risk of the elderly at home is significantly associated with the bathroom. Bathroom issues for the elderly have been prioritised to four main themes: quality, design, cost, and function (Hussain et al., 2023), but for low-income households, the relative order of importance for these theme would be: cost, function, quality, and design. Changing a squat toilet is a priority option for home modification due to limited budget (Jakimovski, 2010) and safety concerns (Krishnan, 2019). House conditions in the rural areas appeared poor, with a high risk of falls. Sub-ethnicity also may play a role in fall risk. Different ethnic groups experience a diversity in quality of life, house style, and house conditions (Seangpraw & Ong-Artborirak, 2020). In northern and northeastern house styles, the bathroom traditionally is located outside the house, increasing the fall risk for the elderly in those areas (Chindapol, 2025). In contrast, northern and southern people use a mattress with a bed for sleeping, which reduces their risk. When combined with the lower socio-economic status of the elderly in rural areas, the elderly in the northeast are the group at the highest risk of falling (Lanna Magazine on Cloud, 2022, as cited in Thammathi, 2013) . Research supports the fact that elderly people with different ethnicity could have different fall risk related to their house characteristics. In India, modification guidelines were recommended for elderly people's homes; however, this was suitable for Western-style homes in urban areas (Chacko et al., 2017). Rural houses in the Indian study were similar to those in the Thai study, as they exhibited below standard construction and the guidelines could not be applied. They also had several fall hazards and an adjustable area for cultural activities, including sleeping arrangements similar to northeast houses. Furthermore, the health conditions of elderly people could be poorer in rural areas than in urban areas because the former have limited access to quality health services. Cultural diversity also influences the acceptance of fall prevention interventions among the elderly in China (Horton & Dickinson, 2011), particularly as influenced by the extended family and vernacular style of the house. Cultural diversity and sociocultural dimensions related to fall risk in the elderly should be a topic of future research.

5.2 Socio-Economic Status Constraints and Falls

This research provides the first statistical evidence supporting the assumption that lower SES correlates with a higher risk of falls among the Thai elderly. Importantly, low income represents only one dimension of SES, and the analysis considers multiple SES-related housing factors. This conclusion is substantiated by two key findings: the significant relationship between all three SES-related housing factors and falls across all five areas ($p < 0.001$) and the significantly higher fall rates among rural elderly compared to urban elderly ($p < 0.05$). These findings are consistent with prior studies. For instance, a previous study in Thailand reported that the low-income group had a higher probability of falls, with poorer groups exhibiting a four times higher fall risk than those with higher incomes (Iamtrakul et al., 2021). Additionally, low socio-economic status was found to be associated with a high degree of loneliness and high risk of falls in the elderly living alone in rural areas (Iamtrakul & Chayphong, 2022). The need for social support, particularly for elderly individuals in low-SES conditions, has been highlighted as critical for enhancing the safety of environment (Shahraki, 2022), as has the importance of diversity in family housing support in both caregiving and financial support (Zanfi et al., 2020).

Socio-economic status undeniably impacts fall risk, as it directly affects the quality of the physical environment and available amenities that support safe living conditions for the elderly. This study demonstrates that elderly individuals in rural areas face higher fall risks due to their lower SES.

Structure instability emerged as a dominant constraint identified in this research, with many rural houses exhibiting leaking roofs and unstable walls. These findings echo previous studies, which noted that rural households generally have lower standards and facility quality compared to urban homes (Cook et al., 2005). The unstable structure of rural homes presents a barrier to modification of houses with safety equipment such as grab bars, or requires a greater budget for stabilization before installation can occur. As a result, elderly individuals in rural areas struggle to achieve safe living environments due to these compounded constraints. House style factors also contribute to SES-related fall risks. This study identified bathroom location, building materials, and bed styles as dominant factors linked to house style. For example, elderly individuals in this study living in the central region had safer house styles compared to those in rural areas. For the central region participants, 63.3% had bathrooms located within the bedroom, of which only 9% required climbing stairs, while just 4% had bathrooms located outside the house. Conversely, in rural areas, 36% of houses had a bathroom located outside, and 48% were built from half-timber and half-cement materials with sharply elevated stairs, a structural condition closely associated with fall incidents. Rural elderly in this study experienced twice the fall risk compared to their central region counterparts (21.7% vs. 10.3%), aligning with prior research findings. This half-timber half-cement house style is not only costly but also requires specific knowledge for modification, with constraints being most significant for rural houses. The use of unsafe building materials and home designs has been shown to increase fall risk (Letts et al., 2010). Furthermore, the inability of rural elderly individuals to afford higher living standards—including safe home facilities—exacerbates their vulnerability to falls (Cho et al., 2013; Chaono & Khunkongme, 2022).

The housing materials of the houses in the study reflected four main types, depending on affordability: timber, cement, gypsum, and galvanised iron. These results underscore the association between house conditions and fall risks. Poorly designed and unsafe home layouts escalate home hazards that increase the risk of falling (Letts et al., 2010). The inability of elderly individuals in rural areas to afford safer, higher-standard housing, further increase their vulnerability (Cho et al., 2013; Chaono & Khunkongme, 2022).

Based on the findings regarding SES and its association with poor housing conditions and increased fall risks, this study further highlights the financial constraints tied to home modifications. Home modification construction costs 24,000 Baht (750 USD in 2021) for minor modifications, 30,500 Baht (953 USD in 2021) for moderate modifications, and 47,000 Baht (1,469 USD in 2021) for major modifications. The minor-to-moderate construction costs were slightly higher than the modification costs in 2016 (ThaiHealth resource Center, 2016). However, the major modification cost was higher than the 45,000 Baht (1,275 USD) estimated in 2016, which mainly was associated with structural reinforcement. This cost increase may be attributed to the special needs of the elderly and increasing construction material costs over the past five years. Scholars have suggested that improvements to mitigate environmental hazards are effective for elderly individuals with limited mobility or health issues, regardless of overall environmental quality (Gill et al., 2000). Moreover, environmental safety can enhance the elderly's comfort and ability to live and move independently (Rand et al., 2011). However, the house conditions result of this study showed that home modifications largely were unaffordable for the elderly, particularly those with low SES. This research provides the first statistical evidence linking SES with fall risks in Thailand, reinforcing that financial instability is a crucial barrier to achieving safe environment for the elderly and addressing home modification needs.

Local governments should pay greater attention to the rural area houses, as these areas have higher risks and limited resources to facilitate home modifications for safety environments. Policy-making should emphasise subsidising higher budgets for home modifications in each house and for rural low-income areas. A warning system may be applied in high fall-risk houses in rural areas to prompt assistance and promote support of elderly individuals who experience falls.

These results are consistent with the SEM and EVT, as they highlight the multilevel influences and compounded vulnerabilities contributing to fall risk (Cannon, 2017). In addition, the application of TPB and CBT suggests that intervention success relies not only on structural improvements (Schoberer et al., 2016), but also on local attitudes, social norms, and individual preferences, further supporting the need for locally adapted policies.

6. Conclusion

This research highlights the inequality arising from socio-economic constraints in implementing home modifications to mitigate fall risks among the elderly. The major findings indicate that elderly individuals in rural northeastern Thailand have the highest fall risks, which correlate with low socio-economic status, substandard housing, and limited access to amenities. The study offers significant evidence of the complex association between low socio-economic status and its limitations in adopting fall prevention strategies, particularly in rural areas like northern and northeastern Thailand (with $p < 0.00$). This not only contributes to knowledge that elderly individuals in these rural regions face greater challenges due to limited budgets and resources for home modifications, but also shows they are constrained by their socio-economic characteristics. Constraints include substandard housing, unsuitable architectural styles with limited or inadequate house utilities, limited access to expertise needed for adapting local housing designs and conditions, and a higher frequency of falls, compared to their urban counterparts.

By categorising home modification costs into three groups—minor, moderate, and major—this research demonstrates that financial constraints prevent low-income elderly individuals from implementing necessary modifications, emphasising the impact of economic disparity on fall risks. This work is among the first to provide quantitative evidence linking economic inequality to health-related outcomes in ageing populations and it expands the understanding of social determinants of health as barriers to fall prevention in low-resource regions. These results contribute new knowledge to the field of ageing and home safety, particularly in the context of developing countries where social inequality remains a significant barrier to healthy ageing. In planning home modifications, equal attention should be given to the socio-economic conditions of the elderly and to their health and environmental fall risk factors.

The findings contribute valuable insight into policy-making by advocating for local government intervention and financial subsidies to improve the quality of life and reduce fall risks for the elderly population. Specifically, the research recommends increasing government construction subsidies by at least 10% of the current budget and including labour costs to ensure feasible and practical implementation. It also underscores the need to prioritize safety-focused designs through universal design principles tailored to the socio-economic conditions and unique needs of the rural environment. Practical recommendations arising from this study include: (1) targeted financial assistance for home modifications in low-income rural areas; (2) policy development to support universal housing designs; and (3) training and guidelines for local architects and builders to address specific problems related to housing conditions and cultural context. In addition, these findings can serve as

a model for other developing countries or regions experiencing similar socio-economic constraints and rapid population ageing. Future research should further explore the long-term impacts of home modifications and conduct comparative studies between rural and urban settings to enhance the generalizability of the results. Prompt and sustained policy actions are essential to reduce health disparities and promote ageing in place for all elderly groups, regardless of their socio-economic background.

This article acknowledges its limitations as part of the larger research project. Key components, such as community selection criteria, control group findings, and environment fall risk mitigation strategies, have not been explained here. The study also does not directly compare local policy protocols and social supports among different areas. The data collected in this research are not normally distribution, resulting in limited statistical analysis and interpretation. Several potentially influential factors, including intrinsic factors, socio-cultural dimensions, body size differences across sub-ethnicities, are discussed in Chindapol (2025). These findings can serve as a model for similar contexts in other developing countries that are grappling with rapid population ageing and socio-economic disparities. In summary, the evidence and recommendations from this study can inform future policy, practice, and research, and can serve as a foundation for strategies aimed at reducing falls and promoting equity in healthy ageing globally.

7. Disclosure Statements

This study is the extended research contributed from the data of the sub-project entitled “Developing healthy environment of the rural Thai elderly”, conducted in 2020. The sub-project was under the research program titled “Appropriate housing for Thai Elderly to promote physical and mental health by Age friendly community concept”, funded by the 2020 National Research Council of Thailand (NRCT) Fund, ID NRCT272/2563. Ethics approval ID: CMUREC63/271. The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Author Contributions

This article has only one author. All sections and content, SC. All author has read and agreed to the published version of the manuscript.

Endnotes

[1] The estimated proportion was based on the total number of accommodations with elderly residents in 2022 (Chuanwan et al., 2022; Registration Administration Bureau, 2024) and on the number of modified and suitably designed accommodations for the elderly subsidised during 2017–2022 by the Department of Older Persons(2022), the National Housing Authority, and other private projects (Phoolkert & Satchanawakul, 2020).

[2] Followed “Budget of home environment modification for the older persons” (Regulation of the Department of Older Persons: guideline and protocol for home environment modification for the older persons and aged-friendly community support B.E.2562: in The Act of Older Persons, Royal Thai Government Gazette, Volume 136, Special issue 145 D, p. 5, 7 Oct 2019)

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