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Abstract

Purpose: Sustainable and resilient infrastructure (SRI) projects aim to reduce flooding impacts and improve community adaptability. For instance, flood-resistant stilts elevate structures, mitigating flood damage. Comprehensive consideration is crucial when adding elements to housing projects, incurring costs for all involved parties. This study assesses concrete stilt viability for cost-effective flood mitigation in Malaysian terrace housing.

Design/Methodology/Approach: The study evaluates cost implications through a comparative 5D Building Information Modeling (BIM) cost analysis of stilted and conventional (standard) housing models. This assesses the percentage increase in total cost. Furthermore, a survey of construction professionals was undertaken. The study utilized the online convenience and stratified sampling techniques. Out of the 222 emails that were sent, 27 construction professionals located in Johor, Sabah, and Selangor within Malaysia participated in the research survey. Their perspectives on stilt housing prospects and factors for costing such structures were analyzed through the descriptive analysis using SPSS.

Findings: The case study models revealed that the incorporation of stilts could lead to a 21.64% increase in the overall cost per unit. This cost increase was primarily attributed to the additional reinforcement required. However, the survey findings highlighted that a majority of construction professionals perceived the cost increment to fall within the range of 10-20%. Consequently, it becomes imperative to meticulously consider cost factors such as foundational requirements, staircases, and the extended construction duration to effectively curtail expenditures. The prospect of heightened costs potentially posing a threat to profit margins and discouraging developers necessitates careful financial management. Notwithstanding these challenges, the survey's insights underscored that professionals in the construction industry indeed recognize the potential of stilt technology in the realm of flood mitigation and management, particularly within housing projects.

Practical Implications: This research has significant practical implications. It provides a precise financial contrast between housing categories using 5D BIM and incorporates construction experts' viewpoints on raised housing. Enhanced design considerations for raised housing can make it economically viable, offering a cost-effective, nature-based approach to flood mitigation. This approach can bring substantial benefits to residents by reducing flood-related damages and enhancing community resilience.

Originality: One of the notable aspects of this research is its originality. It employs a dual quantitative methodology involving modeling and survey techniques to address its objectives effectively. This approach contributes significantly to the relatively limited body of research focused on stilt housing and the application of 5D BIM. By combining these methodologies, the study explores a relatively uncharted area, making a valuable contribution to the field.

Keywords: Architectural design, Building information modelling, Flood mitigation, Stilt housing, 5D BIM

1. Introduction

The focal point of contemporary construction practices is the delivery of sustainable and resilient infrastructure (SRI) projects, acknowledging the imperative for environmentally and economically conscious construction material technologies to enhance building and infrastructure functionality (Soliman *et al*., 2022). In this context, this research delves into the utilization of Building Information Modeling (BIM) techniques, specifically 5D BIM, to assess and compare the costs associated with stilt housing and conventional housing for flood management. BIM entails the development of digital representations of structures, facilitating effective planning and teamwork, thereby empowering the construction sector to produce sustainable, streamlined, and economical buildings (Hemanth and Pedala, 2024). Thus, the estimation of construction project costs using 5D BIM necessitates precise quantity assessments, conventionally conducted through error-vulnerable 2-D drawings. The advent of BIM has enhanced the expediency, accuracy, and reliability of quantity takeoffs (Valinejadshoubi, *et al*., 2024).

The selection of stilt housing, characterized by its elevated structure, and conventional housing, representing more conventional construction methods, becomes a relevant subject for examination. The purpose of this study is to contribute to the ongoing discourse on sustainable and resilient infrastructure by investigating the potential cost implications of adopting innovative solutions in flood-prone regions.Stilt housing, originating primarily from Micronesia and Oceania, has a deep historical lineage within the evolution of human habitation. It stands as one of the earliest adaptations of conventional housing, modified to align with environmental demands. The progression of agriculture further intertwined with societal norms prompted human settlements to congregate along riverbanks and floodplains (Tha *et al*., 2024, facilitating cultivation, transportation, and fishing endeavors (James, 2001). However, these geographies are vulnerable to recurrent inundations arising from substantial precipitation, leading to river and marsh overflows. Consequently, ancestral communities innovated by elevating dwellings on stilts, safeguarding possessions from the recurring deluge.

As of 2022, the population of Malaysia reached 33.4 million (Worldometer, 2022), with approximately 3.5 million Malaysians inhabiting floodplains or flood-prone territories. Notably, 77% of Malaysians reside within urban locales, of which 23% are situated in flood-endangered areas (Khailani and Perera, 2013). Malaysia, marked as a nation with notably intense rainfall, experiences an average annual downpour of 2500 mm (Khalid and Shafiai, 2015). Since the onset of the 21st century, over 4.82 million individuals (22%) have been impacted by floods in Malaysia, spanning a total affected expanse of 29,000 km² and incurring substantial infrastructure impairment, culminating in significant economic ramifications. This percentage is projected to rise due to urban expansion encroaching upon flood-prone zones driven by space constraints within urban centers (Ayog *et al.*, 1998).

Integrating traditional stilt techniques into contemporary architectural frameworks often entails the gradual transformation of rural Malaysian residences. This evolution involves the infusion of modern materials such as concrete, brickwork, and tiling. Consequently, straightforward yet efficient strategies are imperative for constructing flood-resistant housing to pre-empt potential flood. Stilts present a promising solution, although their adoption necessitates supplementary architectural components, inevitably entailing costs for all stakeholders, ranging from developers to contractors and eventual homeowners. The study's motivation stemmed from the findings of Mari *et al*. (2023) which highlighted that the primary obstacles to adopting stilt structures as resilient solutions are the cost and materials involved in their design and construction. As such, the incorporation of BIM for precise cost evaluation, particularly through the prism of five-dimensional (5D) BIM, emerges as a pertinent avenue for both conventional and stilt housing assessment, addressing not only cost concerns but also the crucial aspect of flood management in housing design. Therefore, the research questions of this study are (a) how does the design of the construction impact the overall cost of stilt housing when juxtaposed with conventional housing? And (b) what are the perceptions of construction professionals concerning the cost of stilt housing versus conventional housing? BIM embodies a process involving the generation and management of digital representations capturing a building's physical and functional attributes (Hosseini *et al.*, 2016). It empowers collaboration and coordination among architects, engineers, and construction professionals through a shared digital blueprint of the structure (Tanko *et al.*, 2024). In the BIM paradigm, diverse facets of the edifice, encompassing geometry, spatial relationships, materials, quantities, and attributes, are amalgamated into a three-dimensional (3D) digital framework. This repository of knowledge can be enriched with supplementary data like cost, scheduling, and sustainability criteria. BIM augments visualization, analysis, and decision-making across the building's lifecycle, spanning inception to operation and maintenance. Thus, the implementation of BIM for cost estimation augments data accuracy and the comprehension of the 3D model, consequently engendering more dependable cost approximations. The research landscape reflects growing interest in 5D BIM and the role of quantity surveyors within the construction sector (Banihashemi *et al.*, 2022; Chan *et al.*, 2018; Moses *et al.*, 2020; RICS, 2014).

5D BIM, synonymous with BIM imbued with cost considerations, extends the BIM paradigm by assimilating cost-centric information into the digital schema (Yao *et al.*, 2020). This augmentation facilitates the visual scrutiny and analysis of cost ramifications throughout the project's lifecycle. Stakeholders can deploy 5D BIM to simulate and appraise diverse construction scenarios, gauge the financial repercussions of design alterations, and enhance decision-making efficacy. Recent years have witnessed a plethora of investigations into 5D BIM, with scope remaining for further exploration into its applicability within distinct housing typologies and construction developments (Amin Ranjbar *et al.*, 2021; Baldrich Aragó *et al.*, 2021; Stanley and Thurnell, 2014a). Nonetheless, publications centered on 5D BIM remain modest, constituting a mere 1.4% of the broader BIM discourse (Baldrich Aragó *et al.*, 2021), with none exploring its utilization for comparative estimations of stilt and conventional housing models within the construction arena. Consequently, this study endeavors to ascertain if incorporating concrete stilts into attached terrace housing proves economically viable for flood mitigation in Malaysia. It seeks to assess cost implications by conducting a comparative 5D costing analysis of stilted and conventional housing models, elucidating the extent of total cost escalation as a percentage. Additionally, the research aims to identify prevailing challenges tied to 5D BIM implementation within construction contexts. The study is underpinned by two primary research objectives:

I. To identify the cost differential between stilt housing and conventional housing models, with a specific emphasis on key cost factors.

II. To validate the findings from Objective 1 through an examination of construction professionals' perspectives, thereby confirming the viability of stilt housing.

2. Literature Review

The significance of incorporating indigenous knowledge and customary methods into disaster risk reduction strategies, alongside their integration with scientific knowledge, is paramount. Decision-makers play a vital role in providing suitable assistance to local communities, enabling them to bolster their resilience against the impacts of riverbank erosion and other natural hazards (Tha *et al.*, 2024). Therefore, it is crucial for various stakeholders, including humanitarian organizations and the local community to effectively handle flood risks and flood-related information/knowledge (Along *et al.*, 2022). Sections 2.1 and 2.2 emphasize the significance of SRI projects in alleviating the repercussions of environmental challenges, particularly flooding, through the implementation of resilient design and sustainable construction practices (Burhany *et al.*, 2022). Various studies have investigated stilt housing (Liu, 2019; Zhao *et al.*, 2013; Burhany *et al.*, 2022) as a viable strategy for areas prone to flooding, highlighting the advantages of elevated structures in safeguarding against rising water levels. The adoption of stilts aligns with sustainable practices, minimizing environmental impact, and bolstering community resilience (Fahrianoor and Sanjaya, 2021). Section 2.3 explores the utilization and implementation of 5D BIM.

2.1 Stilt Housing

The utilization of stilts in residential architecture traces its origins back to ancient human history, extending as far as seven millennia. Remarkably, this practice was even prevalent in remote areas like the Swiss Alps, notably in the presence of lakes, where the technology was introduced through interactions with Mediterranean traders (Archaeology World, 2022). A similar phenomenon occurred in the more recent eighteenth and nineteenth centuries, prompted by British colonial influence, which gave rise to a distinctive housing style known as the modular stilt bungalow. This innovation drew inspiration from the local vernacular architecture, such as the elevated Malaysian kampung (village) stilt houses (Chang and King, 2011). These architectural endeavors epitomized the convergence of Western and Eastern architectural elements, devised to harmonize functionality, and serve the accommodation needs of British colonists and envoys in tropical nations such as Malaysia, Indonesia, Thailand, Laos, as well as regions including Africa and the Americas.

Noteworthy historical records include observations made by early South American explorers like Jesuit Joao Daniel, who documented the prevalent practice of constructing homes over water bodies in the Brazilian Amazon rainforest. These dwellings, crafted from wood and hay, were supported by piles of palm tree branches (Navarro, 2018). The genesis of stilt housing stemmed from its pragmatic response to the challenges posed by the natural tropical environment, particularly relevant to inhabitants residing near flood plains and rivers. The distinctive characteristics of tropical climates, characterized by intense rainfall, harsh solar exposure, and the presence of insects and animals (Nolan, 2011), necessitated innovative approaches to coexist with these environmental factors while ensuring human comfort.

Traditional stilt houses were thoughtfully designed, often featuring sizable windows to facilitate effective ventilation and illumination within the structures. Strategic placement of windows at opposite ends of the house aligned with the prevailing natural breezes, enabling cross-ventilation. Traditional architectural choices tended to eschew glass, ~~favoring~~favouring wooden shutters, and in more modern iterations, glass, as apertures for regulating airflow. These design principles were supplemented by the incorporation of net coverings to deter insects. Additionally, the incorporation of expansive projecting roofs served to channel rainwater away from the dwelling and its supporting stilts, thwarting the accumulation of water underneath the structure (Jin and Zhang, 2021; Soni *et al.*, 2022).

2.2 Potential of Stilt Housing in Malaysia

The efficacy of stilts as a technological solution constitutes a pivotal factor in justifying their integration within the built environment of Malaysia. Nevertheless, for stilts to garner appeal among potential homebuyers and other stakeholders, their advantages must extend beyond the mere advantage of elevated positioning during flood occurrences. Table I depicts the potential of stilt housing in Malaysia.

2.2.1 Flood Resistance

In Malaysia, flooding manifests in two primary forms: monsoon floods and flash floods. The former is an annual occurrence induced by the North-east monsoon rains, spanning from early November to March. Conversely, flash floods stem from factors such as impermeable surfaces in urban zones, hindering natural rainwater infiltration and leading to substantial water accumulation (Buslima *et al.*, 2018).

Integral to the success of stilt houses is their capacity to withstand various flooding scenarios. Mari *et al.* (2023) asserted that conventional stilts contribute to flood mitigation by employing hybridized recycled materials in stilt structures, resulting in enhanced structural integrity. During inundations, water surges rapidly and often attain high velocities, generating considerable force, compounded by the presence of debris within the water. Notably, water velocities exceeding 1.6 meters per second pose concerns, as they induce structural strain. The flow's pressure can impose significant tensile and compressive forces on columns, exacerbated by the impact of debris and soil erosion, weakening the overall structure (Kušar and Volgemut, 2014).

2.2.2 Seismic Resistance

Earthquake events constitute highly detrimental natural catastrophes, transcending geographical boundaries. Malaysia's positioning on the Eurasian continental plate has largely shielded it from severe seismic occurrences. However, the 2015 Sabah earthquake revealed vulnerabilities in existing structures, emphasizing the need for additional measures to mitigate seismic ground motions (Mahmood *et al.*, 2022). Despite a relatively low seismic hazard, the prospect of a seismic event recurs, given the proximate Sumatra fault zone and potential reactivation of dormant faults (Marto *et al.*, 2013).

Stilt housing offers significant benefits in earthquake-prone areas due to its unique structural design. By raising the structure above ground level, stilt houses are less vulnerable to ground movements during seismic events (Kušar and Volgemut, 2014). This design minimizes direct exposure to seismic forces transmitted through the ground. The elevated position also allows for more flexible movement during earthquakes, as the structure can sway or shift without being constrained by direct contact with the ground. Additionally, stilt houses often use lightweight materials and flexible construction techniques that can absorb and dissipate seismic energy more effectively than heavier, rigid structures (Mari *et al.*, 2023. These features collectively enhance the seismic resilience of stilt houses, making them a practical choice for reducing earthquake risks in areas prone to seismic activity. Thus, comprehending the performance of stilt housing in such conditions is paramount to engendering enduring residential safety, accounting for potential natural disasters. For a collection of elevated terrace units, the prevailing Malaysian construction practices entail a reinforced concrete framework interlinked among units.

2.2.3 Thermal Comfort

Thermal comfort denotes the body''s natural response to ambient temperature variations. The modernization of Malaysia and global societies has ushered in mechanical means for maintaining indoor temperatures, resulting in heightened energy consumption, exacerbating climate change and flooding implications (Taleghani *et al.*, 2013).

Malaysia's contemporary modular architectural approach, exemplified by terrace housing, emerged as a response to low-income urban housing demands. However, this approach often proves unsuited to the tropical hot and humid climate, leading to suboptimal thermal conditions (Tinker *et al.*, 2004). Nugroho *et al*. (2007) concur, stating that daytime temperature regulation in terrace houses is hindered, unable to counteract rising temperatures attributed to solar exposure. An adept housing design should ensure year-round comfort. The adoption of traditional vernacular architectural techniques in modern construction is not novel. Comparative analyses between Malay traditional houses and modern terrace dwellings (Hassan and Ramli, 2010; Tinker *et al.*, 2004) underscore the former's proficiency in achieving thermal comfort.

Thus, stilt housing offers notable advantages in maintaining thermal comfort, especially in warm climates. Elevating the living space above the ground creates natural ventilation pathways underneath the house, allowing air to circulate and dissipate heat effectively (Nugroho *et al*., 2007). This airflow helps cool the structure during hot weather, reducing the need for mechanical cooling systems like air conditioners. Additionally, the elevated design minimizes heat gain from the ground, which can be significant in areas with high temperatures. Stilt houses often have open floor plans and large windows that facilitate cross ventilation (Mari *et al*., 2023), further enhancing airflow and comfort indoors. The combination of natural ventilation, reduced heat transfer, and thoughtful architectural design makes stilt houses well-suited for providing thermal comfort in warm climates, offering a sustainable and energy-efficient solution for comfortable living.

2.2.4 Building on River and Coastal Regions

Constructing housing on various terrains can be complicated, particularly in the presence of expansive water bodies like rivers and oceans. Sandy or muddy grounds pose challenges for establishing sturdy foundations due to erosion dynamics and the heightened risk of flooding. Nonetheless, dwellings situated in these locales have evolved to confront these specific challenges. A notable exemplar is the implementation of stilt housing in Kalimantan during the significant inundation of January 2021 (Floods in South Kalimantan, 2021). Inhabitants of Tempakang and Halong villages emerged relatively unscathed, encountering minimal casualties and property damage. This accomplishment was attributed to the communities' adeptness at adapting to the prevalent flood occurrences. Measures encompassed a nuanced comprehension of rainy seasons and river behavior, early-age swimming and boating education for children, and furnishing homes with lightweight materials for ease of relocation.

In anticipation of flooding events, residences are elevated on stilts, ensuring that the community can function effectively despite the recurrent and intense flooding, thereby enabling seamless daily activities (Fahrianoor and Sanjaya, 2021). Similarly, riverside settlements in Palembang, Indonesia, and Padma, Bangladesh, employ the highest tide or monsoon water level as a reference point for stilt heights in nearly all their housing units (Lussetyowai and Adiyanto, 2020).

2.2.5 Building on Slopes

Erecting conventional terrace housing on slopes often necessitates extensive earthworks, involving soil removal and embankment creation for level surfaces. However, this method disrupts natural equilibrium by removing stabilizing greenery and trees, reducing rainwater infiltration and exacerbating flooding and landslides (Islam *et al.*, 2021). Alternatively, stilt-based construction emerges as a solution, elevating structures above sloping terrain, minimizing environmental disruption, and preserving the natural landscape (Ilieş *et al.*, 2015).

Stilt housing presents a practical solution for building on slopes, offering several advantages in such terrain. By utilizing elevated foundations and columns, stilt houses can adapt to varying gradients and uneven landscapes without extensive excavation or modification of the natural terrain. This construction method minimizes disturbance to the slope and reduces the need for extensive earthwork, making it a more environmentally friendly option (Ilieş *et al*., 2015). Additionally, stilt housing can be designed to follow the contours of the slope, optimizing the use of space, and preserving natural features of the landscape. The elevated position also provides enhanced views and improved ventilation, further enhancing the appeal of stilt houses in sloped areas. Therefore, stilt housing demonstrates great potential for building on slopes, combining structural adaptability with minimal environmental impact.

Table I.

Potential of Stilt Housing in Malaysia

2.3 BIM

BIM technology encompasses a procedural approach involving the creation of comprehensive information models integrating graphical and non-graphical data within a shared Common Data Environment (CDE), which functions as a centralized repository for digital designs (Pilyay and Shilova, 2018). The inherent object-oriented nature of BIM models, equipped with embedded parametric data, facilitates the precise quantification of structural components, and enables more accurate estimations with fewer discrepancies and omissions (Banihashemi *et al.*, 2022). Thus, the benefit of utilising BIM has been acknowledged as a crucial element contributing to the success of projects (Wang *et al*., 2024).

In Malaysia, the adoption of BIM is still in its early stages, as indicated by Che Ibrahim (2018) and Othman *et al*. (2021). Nevertheless, the construction industry has played a crucial role in facilitating the transition to BIM-based technology, as highlighted by Othman *et al*. (2021). Al-Ashmori's study in 2020 identified trust, respect, commitment, early involvement, and knowledge as key driving factors behind BIM implementation in Malaysia. Additionally, Husain *et al*. (2018) found that client organizations in Malaysia generally show a high degree of acceptance for BIM. However, the slow pace of implementation can be attributed to factors like insufficient awareness, high costs, slow adaptation, and the absence of clear guidelines for organizations and policymakers, as noted by Othman *et al.* (2021).

Similarly, Sinoh *et al.* (2020) discovered that, for successful BIM implementation among Malaysian Architectural, Engineering, and Construction (AEC) firms, non-technical elements such as management, leadership, and coordination hold greater significance than technical aspects like software and hardware. Thus, the effectiveness of information sharing among Malaysian BIM practitioners relies on organizational behavior, with support from collaborative constructs, as emphasized by Che Ibrahim (2018). Consequently, BIM has a significant impact on enhancing collective and collaborative information sharing within a virtual environment.

An integral facet of BIM's application involves the amalgamation of digital depictions of building components with temporal and financial information, a practice known as 5D BIM, constituting a prominent BIM use case (Nast and Koch, 2021). The efficacy of the architectural and structural design process hinges on both the richness of the data encapsulated within the design and the viability of data verification procedures.

2.3.1 5D BIM

The conception of 5D BIM was initially formulated in 2008, representing a functional extension grounded in the 3D digital modeling of conventional architectural, engineering, and construction (AEC) undertakings (Yao *et al.*, 2020). The evolution of 5D (Cost) capabilities is progressively gaining traction, and forward-looking project cost management entities are embracing this innovative approach to bolster their competitive edge (Smith, 2014).

5D BIM entails the fusion of 3D-BIM with the fourth dimension (time) and the fifth dimension (cost) data, as underscored by prior research (Chan *et al.*, 2018; Nast and Koch, 2021). The merits of 5D BIM lie in its capacity to dynamically recalibrate real-time costs when design alterations occur, as these modified components can be automatically computed. This functionality facilitates the ongoing monitoring of actual expenditure, ensuring project efficiency within budgetary limits (Yao *et al.*, 2020). According to Baldrich Aragó et al. (2021), a comprehensive 3D model, rich with information, should be established by Quantity Surveyors (QS) and the design team during the project's initial phases to lay the groundwork for the successful application of 5D BIM.

The primary advantages stemming from the adoption of the 5D BIM methodology encompass enhanced efficiency, augmented visualization, early risk identification (Stanley and Thurnell, 2014), and precise cost estimation. Improvements in the visual representation of the 3D model augment satisfaction levels while minimizing uncertainties pertaining to cost fluctuations, benefiting both QS and clients during project execution. Eastman et al. (2011) emphasize that 5D BIM aims to establish links between cost elements and discernible, quantifiable features of model objects, facilitating cost projections and the real-time tracking of expenditures within the BIM framework.

However, the global implementation of 5D BIM remains relatively limited, including in countries like the USA (Olsen and Taylor, 2017). Although, a search for the term "5D BIM" in the Scopus database, along with the utilization of VOSviewer visualization software, yielded 85 documents, 588 keywords, and 225 authors across 34 countries globally. This indicates that the subject being studied is broad and extensively explored in regards toin regard to its comprehensive coverage, diverse viewpoints of researchers, and global relevance. Figure 1 demonstrates the emerging nature of 5D BIM, finding applications in architectural design, project management, BIM, construction projects, cost estimating, and quantity surveying fields. While various 5D BIM software options like CostX and Cubicost exist (Tanko and Mbugua, 2022), this study specifically employed the Cubicost 5D BIM software.

Figure 1.

Visualization of 5D BIM in construction

2.3.2 'Cubicost' BIM-Based Quantity Take-Off

Cubicost 5D BIM serves as an all-encompassing solution for construction cost estimation and management, employing advanced technology and databases to ensure precise and efficient cost estimation in the construction industry (Seghier *et al*., 2022). This system is equipped with key features such as database integration, automation, and customization. Through the integration of extensive databases containing material prices, ~~labor~~labour rates, and other cost factors, Cubicost 5D BIM provides real-time and region-specific information. The automation capabilities streamline the quantity take-off process, minimizing manual errors and enhancing overall efficiency. Additionally, users have the flexibility to customize cost models according to project-specific requirements, ensuring adaptability in the estimation process (Kun *et al*., 2023).

The Cubicost 5D BIM incorporates various cost models, including the unit rate model, parametric model, location-based model, and life cycle costing. The unit rate model calculates costs based on predefined unit rates for different construction components while the parametric model utilizes mathematical relationships and parameters to estimate costs (Banihashemi *et al*., 2022). The location-based model considers the geographical location of the project, adjusting costs based on regional variations in material and ~~labor~~labour prices. Furthermore, the life cycle costing model considers not only initial construction costs but also long-term operational and maintenance costs, aligning with the insights of Swaffield and McDonald (2007).

Figure 2 illustrates the 'Cubicost' BIM-Based Quantity Take-Off process. The initial step is the "Pre-Measurement" phase, which emphasizes the importance of modifying project settings to accurately reflect the project details before commencing measurement. Adjustments should be made to settings related to floors, concrete grades, calculation rules, rebar settings, anchorage, tension/compression settings, and wastage settings. It is recommended to thoroughly review the calculation rules to customize default information based on the specific project requirements. The second step involves "Importing Drawings". Prior to drawing, it is necessary to import drawings, such as CAD or PDF files, using the drawing manager located within the "identify" function tab. Subsequently, the drawings are split and aligned with the axis gridline. The "Draw" function tab encompasses all tasks associated with drawing entities. In the third step, a BIM model is created either by tracing and drawing the entities or by importing a BIM model. The fourth step entails generating the quantity report. Before proceeding, it is crucial to verify and confirm the standard method of measurement being integrated. Once confirmed, quantities are calculated, and expressions are examined. Finally, the last step involves viewing the created entity in 3D using the "View" function tab or utilizing the dynamic view option provided by the Viewing Toolbar.

Figure 2.
'Cubicost' BIM-Based Quantity Take-Off

The process simplifies the Quantity Take-Off procedure and enables automated adjustments of quantities at any time. By incorporating built-in formulas for standard parameters such as concrete volume and formwork area, the software can automatically derive these quantities once the elements are selected or identified (Seghier *et al*., 2022).

The process depicted in Figure 2 possesses the capability to conduct model validation automatically, promptly notifying the user of any invalid modelling or instances of element overlap or clashes. Detailed expressions and comprehensive breakdown calculations, including deductions, can be thoroughly reviewed. Consequently, the adoption of BIM-based Quantity Take-Off significantly reduces variations encountered throughout the project, as discrepancies are effectively eliminated.

3. Methodology

The research methodology encompasses a case study developed from a costed BIM model, derived from actual architectural drawings of a block of terraced housing. Using the software 'Cubicost' by Glodon™, two sets of conventional (standard) terrace units (intermediate and corner) were generated from these drawings. Subsequently, a second set of models was created, incorporating stilts, staircases, and other relevant additions that necessitate consideration. Both sets of models were subjected to cost analysis, leveraging current cost data available from the Malaysian Public Works Department (Jabatan Kerja Raya Malaysia-JKR) Ratol website. A comparative assessment was then conducted to discern the overall percentage increase in costs between the two sets. This cost comparison serves to provide insights into the cost-effectiveness of employing stilt-based housing solutions for flood mitigation. Notably, the case study models encompassed both corner and intermediate terraced units, which were evaluated in both standard and stilted configurations.

3.1 Visualisation of the models

The visualisation of the models consists of the front and side elevations of standard and stilted terrace house models.

Figure 3.

Front and Side Elevations of Standard and Stilted Terrace House Models

3.2 Building Elements of stilted terrace house

Stilted houses encompass various building elements, including the foundation and stilt system, floor structure, superstructure, roofing, utilities and services, and ventilation (Zhao *et al*., 2013). This construction method, highlighted by Burhany *et al*. (2022), offers notable environmental advantages as a sustainable technology compared to alternative approaches. In the context of stilted terrace houses, the foundation plays a crucial role in ensuring stability and supporting the structure, requiring deep penetration into the ground to enhance load-bearing capacity. The raised floor system, constructed using materials such as concrete, steel, or wood, is tailored based on design preferences and structural requirements, as noted by Fahrianoor and Sanjaya (2021). Exterior cladding materials, which often include weather-resistant options like timber, metal, or composite panels, exhibit variability. Stilted houses typically incorporate pitched roofs to improve rainwater drainage and mitigate the risk of waterlogging (Zhao *et al*., 2013). Plumbing and electrical services are strategically positioned within the elevated structure, frequently concealed within walls or floor structures, and the design considerations encompass elevated windows and openings to facilitate natural ventilation and ample ingress of natural light (Liu, 2019).

For the functional operation of the stilted house in this study, standard single-story components were integrated, including ground floor slab, beams, and columns. The area of a single floor measures 244 square meters. The existing ground floor slab was elevated onto added columns, and 1.25m was extended to the back to accommodate the new spiral staircase. The suspended first floor slab replaced the original type of slab. Columns between the ground and first floor were positioned at a recommended 2.5m stilt height and were constructed with stronger grade 30 concrete, aligned with foundation column rebar layout, to withstand flood forces. The reinforcement used includes 10mm and 12mm yielding rebars in pile caps, slabs, and floors, as well as 6mm, 8mm, 10mm, 12mm, 16mm, and 20mm rebars in columns and beams. Additionally, 8mm, 10mm, and 12mm rebars were utilized in the staircase, and 10mm and 12mm mesh reinforcement were incorporated. It's important to note that the 6mm and 8mm rebars were mild steel bars, while the other sizes were composed of high-yield steel. The vertical rebar spacing in columns, beams, and staircases falls within the range of 150mm to 200mm, while in slabs, it is set at 200mm. For ties and links, which have diameters of 8mm and 10mm, they are evenly spaced at intervals of 150mm along the length of the columns, beams, and staircase.

Connecting beams and the ground floor slab adhered to the original standard house design's grade and rebar arrangement. The shared brick wall between the houses was extended to the added floor's base. To comply with Malaysian Uniform Building By-laws of 1984, two entry/exit staircases were installed at the front and back. The former under-stair storage space now serves as the front entrance with a straight run staircase, while the back entrance features a spiral staircase connecting to the added first-floor slab to save space. Both staircases in this study were reinforced with concrete, designed based on average rebar specifications from Cubicost.

3.3 Questionnaire Survey

In this study, a systematic methodological approach was employed. It began with the formulation of precise research questions and objectives, setting the foundation for the research. Subsequently, a questionnaire was designed, incorporating both close-ended 5-Likert scale questions to gather the data. To ensure the representativeness of the collected responses, the study defined a clear target population and applied the online sampling technique. This approach entails contacting individuals via online platforms, such as email, to collect responses for a survey or questionnaire. It constitutes a form of convenience sampling, where participants are chosen based on their availability and willingness to take part, rendering it a practical method for conducting online surveys. Additionally, to uphold the integrity of the major variables, a reliability test was conducted. Finally, the acquired data underwent a descriptive analysis, facilitating an informative summary of the study’'s findings. This methodological framework underpinned the study’'s credibility and yielded valuable insights. The choice to employ questionnaires in the validation survey was imperative because a structured approach was required to collect responses to obtain quantitative data. This was particularly relevant because the survey questions were standardized and came with predetermined response options. The convenience sampling was employed to target professionals who had been categorised into predetermined groups of AEC professionals. Hence, the use both convenience and stratified sampling techniques. ~~T~~The survey involved diverse construction professionals: architects, engineers, quantity surveyors, developers, contractors, valuers, property maintenance experts, and academics. The survey was distributed via email, using addresses obtained from thorough searches on Malaysian construction business and institute websites. Professionals were contacted and invited to participate. Out of the 222 emails sent, 27 respondents actively participated in the research questionnaire, resulting in a response rate of 12.2%. The reduced response rate can be attributed to the limited number of construction professionals with practical experience in building stilt houses, as mentioned by Mari et al. (2023). Among these, 22 were identified as Malaysian construction professionals, and 5 were international professionals currently working in Malaysia. All respondents were in the states of Johor, Sabah, and Selangor. Out of the survey participants, the majority, comprising 22 respondents, were Malaysian residents. Additionally, there was a single respondent each from China, the United Kingdom, Australia, Germany, and Nigeria. In terms of professional backgrounds, the participants were diversified, with 5 professionals identifying as developers, 7 as quantity surveyors, 6 as architects, 4 as engineers, 2 as valuers, 1 as an academic, 1 as a property maintenance expert, and 1 as a contractor. This diverse composition of respondents provides a broad spectrum of perspectives for the study. ~~The research utilized the online stratified sampling technique, which involved categorizing construction professionals into distinct strata based on their respective professions.~~ This approach guarantees the inclusion of every subgroup within the sample.

Table II shows the examination of the internal consistency of factors in the study through a validity and reliability test indicated a value of 0.734 for a set of nine items concerning “participants’ perspectives on the potential of stilt housing” and 0.710 for a pair of items pertaining to “participants' viewpoints on cost considerations associated with additional stilts" Both values surpass the threshold of 0.710, as specified by Hair et al. (2013).

Table II.

Validity and reliability statistics

4 Findings and Discussion

Examining the cost comparison will offer insights into the economic feasibility of sustainable approaches, underscoring the significance of resilient infrastructure in areas susceptible to flooding. It is suggested to factor in life-cycle costs, aligning with the broader discussion on sustainable development.

4.1 5D BIM Costing

4.1.1 Cost Comparison Between Stilt Housing and Conventional Housing Designs

The cost models utilized in this study were derived from architectural and structural drawings obtained from a real-life terrace housing project, as outlined in Section 3.1. In accordance with the standard model, the constituent elements of the structure, including beams, walls, and columns, were made in adherence to the specifications provided in the architectural plans. The stilted model, in accordance with the provided specifications for the rebar and design, underwent modifications on the ground floor level, including the addition of two staircases, beams, columns, and a slab. The consistent element across all models is the uniformity of the number of window and door openings, both externally and internally, in the dwellings. The quantities for each of the dwellings were calculated and valued using the JKR website and organized into a Bill of Quantities (BoQ) to provide a comprehensive breakdown of the expenses for both types. The amounts specified in the BoQ were compiled and organized in a comparative table, depicted in Table III.

Table III.

Cost comparison of stilted and standard terrace housing

The combined cost for an average standard terrace house, including corner and intermediate units, was RM 131,606.95. In contrast, major construction works for a stilted average terrace house amounted to RM 160,081.40. This reflects a price difference of RM 28,474.45, representing a 21.64% increase per unit. The rise in construction costs for a residential unit is relatively reasonable based on comparisons (Property Guru, 2021). The addition of a floor divides the construction cost into three parts instead of two. Additionally, incorporating more floor area can lower the cost per square foot. Introducing stilts to terrace units will inevitably raise overall costs. While this cost increase is evident, understanding its extent and identifying areas of highest expenditure is vital for effective integration of this technology in housing projects.

Rebar costs, accounting for around 25% of the RM320,162.80 total, dominate expenses for intermediate and corner stilted terrace units. Interconnected columns, beams, and slabs require an extra two metric tonnes of rebar for the combined structure, leading to at least one metric tonne increase per unit. To minimize costs when implementing stilt technology in new housing, architects and engineers may need to strategize rebar reduction, although this is bounded by structural integrity and layout concerns. It's more practical to target a price cut approximating the original 21.64% increase due to rebar use in a typical terrace house.

Finishes rank as the second key cost factor for a stilted house. The 736m^2 increase in finish area results from extra column faces and raising the ground floor, accommodating a ceiling. Diverse types and qualities of paint and materials are available. Given its flood-resilient purpose, investing in premium external paint for components likely to face damage and repainting seems unlikely for both developers and buyers at this supplementary level.

4.2 Survey Analysis

4.2.1 Participants views on the Prospects of Stilt Housing

In this section, construction professionals were surveyed about their viewpoints on stilt housing's potential prospects (P1-P9). They were also asked about their agreement levels with stilt housing statements and their opinions on risks and usage. Table IV shows scales, means, deviations, and rankings for P1-P9 prospects. The study investigated stilt houses' effectiveness in flood mitigation. It assessed if elevating houses is a feasible solution, explored extra space practicality, and considered if flood-prone regions should mandate stilt housing. P9 focused on risks during stilt house construction.

Top-ranked P3 (Mean = 4.22) suggests elevating homes could provide parking space, easing road congestion. Shaded elevated spaces could benefit too, addressing traffic congestion issues (Singh et al., 2021). P1, the second-ranked prospect (Mean = 4.04), indicates stilted houses can protect occupants and belongings from floods if constructed robustly and elevated adequately. Site-specific flood levels must be considered. P2, P5, and P8 ranked third to fifth, revealing close links. Extra space under raised floors enhances property value and usage potential (Buczynski, 2018).

P9, exploring stilt housing drawbacks, garnered similar consensus to P1-P8. This implies broad acknowledgment of stilt housing benefits and concerns alike.

Table IV.

Participants views on the prospects of stilt housing

4.2.2 Participants views on cost considerations of added stilts

In this part, building professionals addressed cost aspects related to raising residential structures on stilts. These aspects included foundations, extra excavation, fire protection, extra stairs, extra concrete, scaffolding, extra time, and extra labour. Findings indicated that 19 participants (70.37% of the total) prioritized 'Foundations' when considering costs for stilt-supported houses. This is likely due to the complexity of determining suitable foundations, considering site conditions, pile capacity, and expected building loads (Riley & Cotgrave, 2004). Stilt housing must endure flood-induced stresses, likely demanding reinforced foundations to handle sudden column loading. Strengthening foundations would increase overall development expenses by requiring more robust materials like concrete and rebar.

The next consideration in adding stilts to residential structures includes “extra stairs”, suggested by Templer (1994), and the allowance of “extra time”. Incorporating additional staircases is vital to ensure convenient access and swift evacuation during emergencies. Allotting more time to the project, though likely, is a variable factor. For maximum load-bearing capability, stilts need sufficient time to set, like typical concrete structures (Popovics, 1998). Adding time for each house extends the project duration, but effective time management and installation strategies can mitigate this, satisfying clients and stakeholders (Bordoli & Baldwin, 2010). While significant, this factor can be effectively addressed by an efficient project team. Participants estimated the cost increase from adding concrete stilts, extra staircases, rebar, and formwork. Table V indicates that, about 59% of professionals held an optimistic view, anticipating a modest 10-20% rise in costs due to stilts. Cost increases of less than 10%, 20-30%, and 30-40% were attributed to 7.4%, 18.5%, and 14.8% of professionals, respectively.

Table V.

Participants' views on percentage increase in cost with the addition of stilts

Expanding on the aspect of cost, the respondents were asked regarding the potential viability of silt dwelling as a financially efficient resolution to the issue of residential flooding in Malaysia. Approximately 93% of the professionals examined expressed their belief ("Yes-45%" and "Maybe-48%") in the feasibility of stilt technology as a cost-effective solution to flooding. They supported their viewpoint by highlighting how stilts could serve as a cost-effective alternative for mitigating significant damage to residential areas, obviating the necessity for more complex engineering strategies like extensive drainage systems and flood walls. However, 7% did not see the potential viability of silt dwelling as a financially efficient resolution to the issue of flooding.

4.3 Cost Analysis, Viability of Stilt Housing and Practical Implications

Stilt housing, characterized by raised foundations, offers a potential solution to mitigate the risks associated with flooding and other natural disasters in vulnerable regions. However, the financial implications of adopting this housing model compared to conventional methods are a subject of scrutiny. The first objective of this study was to identify the cost differential between stilt housing and conventional housing models. Analysis of case study models revealed a notable increase in the overall cost per unit when stilts were incorporated. Specifically, the findings indicated a 21.64% rise in costs per unit. This increase was predominantly attributed to the necessity for additional reinforcement to support the raised foundation of stilt housing. While stilts provide resilience against flooding, the added structural requirements contribute significantly to the overall construction cost.

To validate the findings from the cost analysis, the study sought input from construction professionals. Through a survey, professionals were asked to provide their perspectives on the cost implications of stilt housing. The survey findings revealed that a majority of respondents perceived the cost increment associated with stilt housing to fall within the range of 10-20%. This alignment between the survey results and the case study findings provides validation for the identified cost differential. The identified cost differential between stilt housing and conventional models underscores the financial considerations associated with adopting this alternative housing approach. While the increase in costs may present a challenge, particularly in budget-constrained environments, it is essential to evaluate the long-term benefits and resilience offered by stilt housing. By mitigating the risks of flooding and other natural disasters, stilt housing can potentially yield substantial savings in terms of property damage and disaster recovery efforts.

In terms of practical implications, an escalation in house construction costs affects all stakeholders, including developers, buyers, and the government. The varied actions of these stakeholder's influence project outcomes and effectiveness. For developers, a 22% construction cost increase per unit might not seem significant individually, but when scaled up, it becomes problematic. However, this rise could strain some developers' resources. While higher costs challenge a developer's profitability, the potential for increased unit density due to additional space could offset this. Stilt homes' appeal lies in their resilience against floods, a strong selling point for buyers. Stilt homes could prevent project failures, adding value to developers' endeavors.

Following annual floods, government and public sectors relocate affected communities to safer areas (Nurdini *et al*., 2021). Yet, resettled communities often face housing, job, and opportunity shortages, impeding recovery and fostering resistance to rebuilding. Economic constraints make self-initiated moves difficult for flood-prone area residents (Chan and Parker, 1996). The government should emphasize pre-disaster risk management (Khalid and Shafiai, 2015) to bolster community resilience, fostering growth by safeguarding assets from flood damage. While not the cheapest option, stilt houses enhance self-sufficiency, safety, and flood preparedness.

Regardless of reasons, Malaysia's flood risk is increasing, imperilling more homes. Stilt housing addresses this concern, shielding buyers from floods, safeguarding their belongings, and increasing property value by offering additional space and lower cost per square foot. Elevated structures also reduce property and possession damage risks, leading to higher insurance coverage. Additionally, stilted terrace houses introduce a novel housing option, potentially garnering greater desirability due to their distinctiveness (Chai, 2021).

5 Conclusion and Recommendations

The application of stilt technology within the context of Malaysian terrace housing presents a promising avenue for enhancing the self-sufficiency of residents in flood-prone regions. While not without limitations, this approach offers increased resilience, heightened personal safety, and improved protection of assets against flood hazards. The impetus behind adopting stilt housing arises from growing global concerns about climate change's impact on Malaysia's hydrological system. Escalating flood severity and frequency necessitate alternatives to conventional hard engineering solutions, such as costly drainage systems, flood barriers, and dams, which often disrupt natural dynamics and are constrained by design limitations.

Through a survey of construction experts in this study, most respondents endorsed propositions related to stilt housing potential, underscoring industry awareness of its benefits and prospects. Professionals' cost estimates, indicating a 10-20% increase in project costs, aligned with findings from a comprehensive cost model case study. This reinforces the understanding that adopting this technology mandates developers to anticipate and address heightened project costs. Notably, foundations emerged as a crucial cost variable due to increased elevation and flood-induced load implications, potentially demanding reinforced foundations. Despite a 93% consensus on the cost-effectiveness of stilt housing, its integration remains uncommon in Malaysian housing projects due to budget constraints and focus on alternative flood mitigation methods.Therefore, the cost analysis conducted in this study sheds light on the financial considerations associated with stilt housing compared to conventional models. While the incorporation of stilts incurs a notable increase in construction costs, the benefits in terms of disaster resilience justify this investment. Moreover, the validation of findings through construction professionals' perspectives provides confidence in the viability of stilt housing as a practical solution for mitigating the risks of natural disasters. Moving forward, policymakers, developers, and communities should consider the long-term advantages of stilt housing in enhancing disaster resilience and sustainable development efforts.

The limitations of the study include the exclusion of mechanical, electrical, and plumbing (MEP) components from cost analysis. It is crucial to emphasize that the following factors were not considered when calculating the cost: the contract approach (whether traditional or design and build) and fees for professional services. The rates specified in a BoQ encompass both material and labor costs. Enhancing thoroughness and precision in future iterations could involve incorporating these aspects for more meticulous cost assessment. Furthermore, broadening the study's scope to encompass additional design aspects of terrace housing and utilizing physical or BIM tools to simulate concrete stilts under various flood scenarios would yield deeper insights into optimal stilt implementation for robust performance and resilience. The study's limitation also lies in the use of a limited sample size, which will reduce the ability to make broad generalizations and increase the risk of Type II errors, that is the potential to overlook genuine effects. Nevertheless, it is important to note that the research objectives are well-suited to the capacity and limitations of the selected sample size, particularly in validating objective 1 as the study concentrates on construction professionals who share similar characteristics, and the target population is relatively small and specialized. It is recommended that the long-term cost implications, including maintenance and operational costs, for stilt housing versus conventional housing should be researched. The outcome of the research will enhance the existing knowledge base concerning SRI projects, providing pragmatic insights for decision-makers, urban planners, and construction professionals. Suggestions regarding the implementation of 5D BIM in upcoming infrastructure projects should be explored, emphasizing its capacity to promote sustainable and resilient development.

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FIGURES

Figure 1. Visualization of 5D BIM in construction

Figure 2. ‘Cubicost’ BIM-based quantity take-off

Figure 3. Front and side elevations of standard and stilted terrace house models

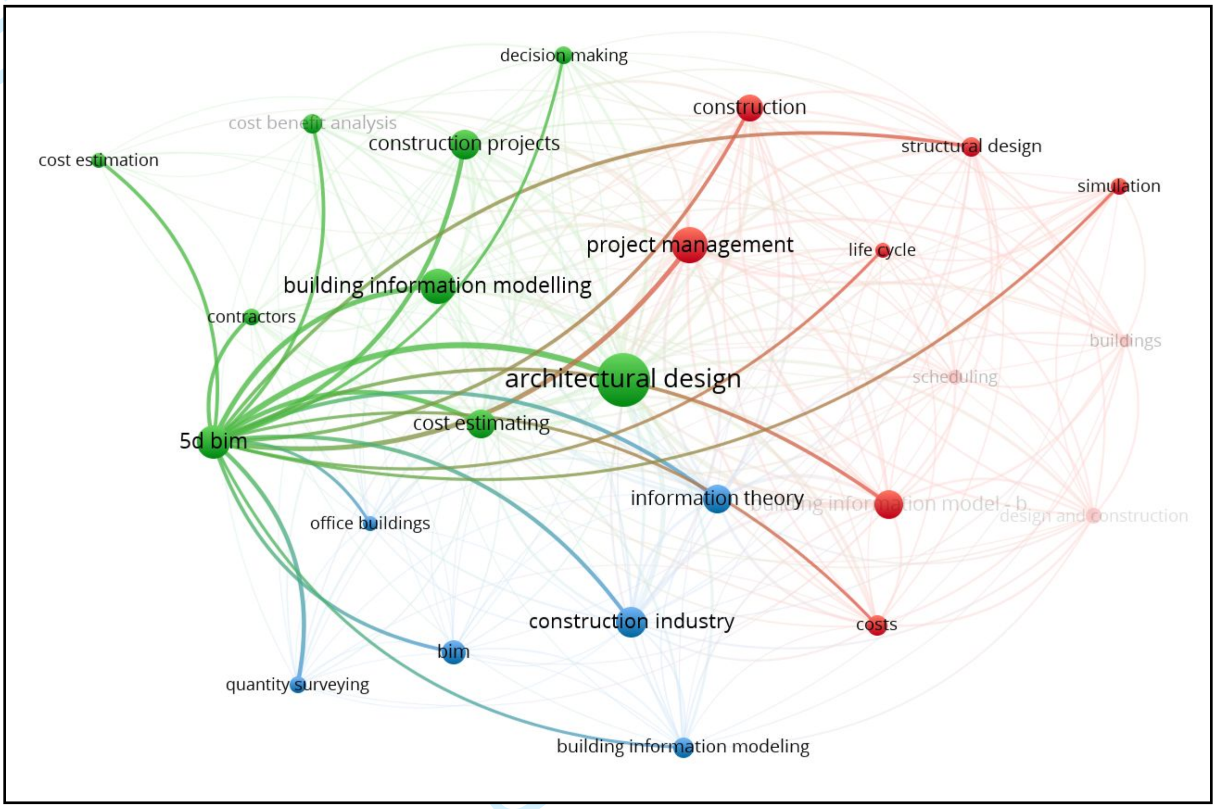

Figure 1. Visualization of 5D BIM in construction
Source: Created by the authors

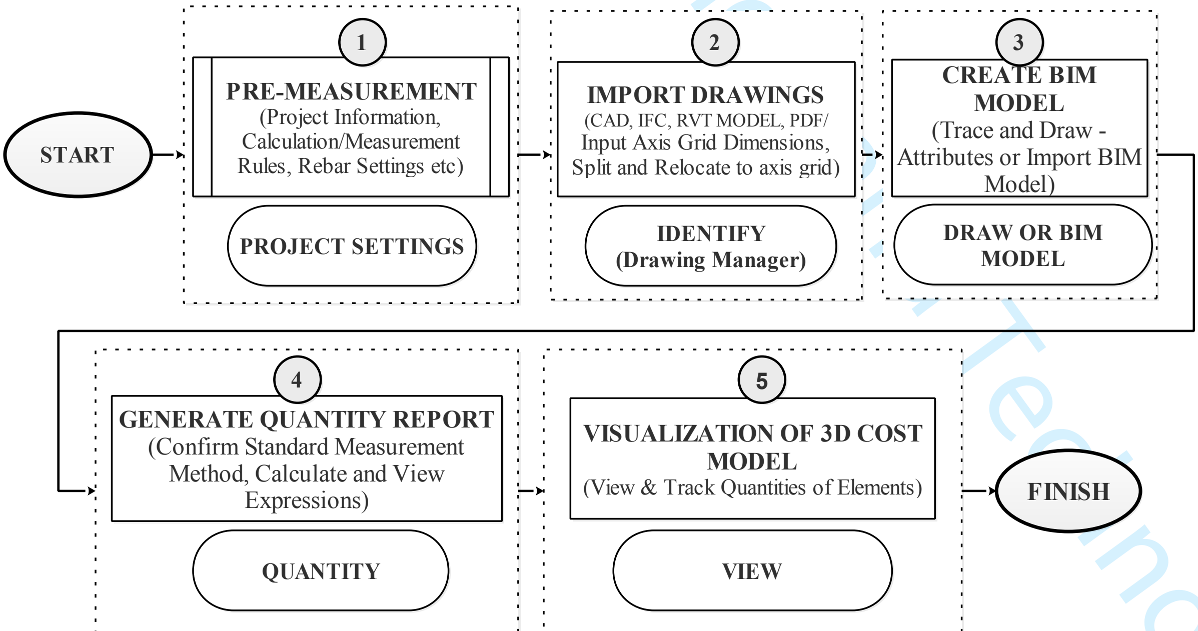

Figure 2. 'Cubicost' BIM-based quantity take-off
Source: Created by the authors

Standard Terrace House Model	Stilted Terrace House Model

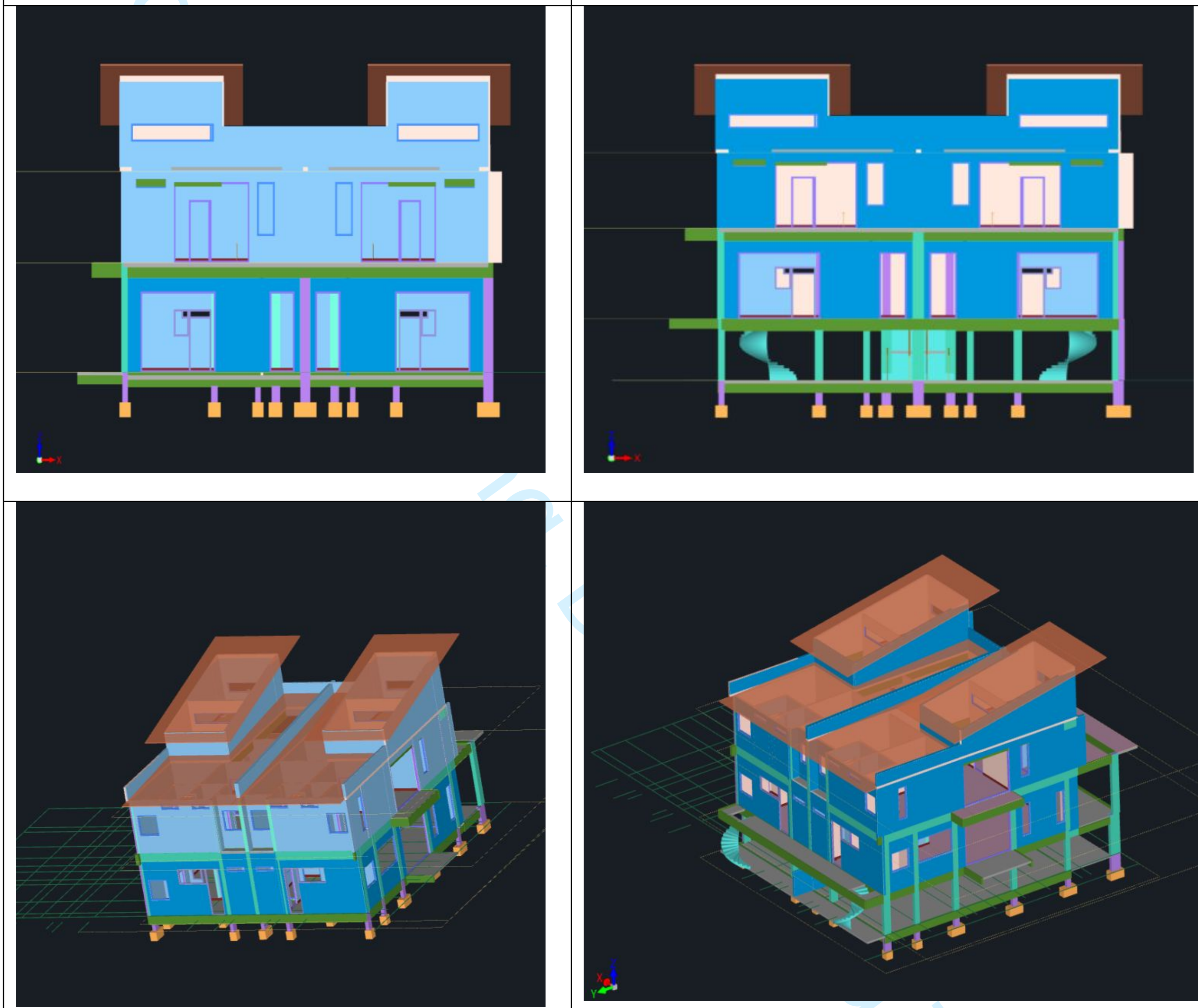

Figure 3. Front and side elevations of standard and stilted terrace house models
Source: Created by the authors

TABLES

Table I. Potential of Stilt Housing in Malaysia

Title	Authors & Year	Potential	Remarks
Flood and Flash Flood Geo-Hazards in Malaysia	Buslima, Omar, Jamaluddin & Taha (2019)	Flood Resistance	Flood disaster mitigation and vulnerability reduction.
Re-Establishing Traditional Stilt Structures in Contemporary Architecture–the Possibilities	Mari, Liew & Ng (2023)	Flood Resistance	Enhancing flood mitigation through the utilization of hybridized recycled materials in stilt structures with improved structural properties.
Construction of Residential Buildings on Columns as an Alternative to Construction In Areas Exposed to Floods	Kušar & Volgemut (2014)	Flood Resistance & Seismic Resistance	Utilizing innovative materials and structural principles for elevated construction in seismic and flood-prone regions with low bearing soil.
Effect of Inadequate Lap Splice Length on the Collapse Probability of Concrete wall Buildings in Malaysia	Mahmood, Vafaei, Alih & Masoomi (2022)	Seismic Resistance	Utilizing high-quality concrete walls and exterior frames for seismic ground motion mitigation.
An Evaluation of Thermal Comfort in Typical Modern Low-Income Housing in Malaysia	Tinker, Ibrahim & Ghisi (2004)	Thermal Comfort	Optimizing thermal comfort through the integration of insulation and ventilation design in elevated stilt housing. elevating structures effectively mitigates heat gain during hot weather and minimizes heat loss during colder seasons, enhancing overall thermal comfort.
Natural Ventilation of Indoor Air Temperature: A Case Study of the Traditional Malay House in Penang	Hassan & Ramli (2010)	Thermal Comfort	Enhancing thermal comfort through the integration of a natural air ventilation system in stilt housing. elevating the structure minimizes direct contact between living spaces and the ground, effectively reducing heat transfer.
A Preliminary Study of Thermal Comfort in Malaysia's Single Storey Terraced Houses	Nugroho, Ahmad & Ossen (2007)	Thermal Comfort	Optimizing thermal comfort and energy efficiency in single-storey terraced houses through the integration of natural air ventilation systems. the incorporation of stilts provides shading for the lower portion of the house, effectively reducing solar heat gain through windows and walls.
Patterns of Adaptation of Riverbanks Communities in Facing Flood Disaster in South Kalimantan	Fahrianoor and Sanjaya (2021)	Building on River and Coastal Regions	Elevated stilt houses: resilience against flooding in river and coastal regions. their elevated design offers protection from heavy rains and storm surges.
A Study on Urban Spatial Patterns of Riverside Settlement: A Case Study of Musi Riverside, Palembang	Lussetyowai and Adiyanto (2020)	Building on River and Coastal Regions	In coastal regions susceptible to hurricanes or tropical storms, stilt houses offer enhanced resilience against storm surges when compared to houses constructed at ground level.
Improving the stability of Slopes with the aid of Underground Houses	Illies, Moldovan & Moldovan (2015)	Building on Slopes	The implementation of reinforced concrete walls serves as an effective solution to mitigate flooding in regions with slope-sliding risks. Stilt-based construction over sloping terrain minimizes environmental disruption while preserving the natural landscape.

Source: Created by the authors

Table II. Cost comparison of stilted and standard terrace housing

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
.734	.730	9
.710	.710	2

Source: Created by the authors

Table III. Cost comparison of stilted and standard terrace housing

Aspects of the Main Building Work		**Standard Terrace House (Corner & Intermediate Units)**		**Stilted Terrace House (Corner & Intermediate Units)**	
Items	**Unit**	**Amount**	**Cost (RM)**	**Amount**	**Cost (RM)**
Foundations	nr	49.00	5880.00	49.00	5880.00
Concrete	m^3	106.83	29912.40	145.82	42069.85
Formwork	m^2	1099.12	28125.52	1452.40	36273.90
Rebar	t	12.85	45697.07	16.00	73000.27
Brick	m^2	810.34	38879.84	840.37	41041.08
Roof	m^2	556.38	38946.88	556.38	38946.88
Finishes	m^2	2649.51	38342.28	3389.05	45520.92
Door & Windows	nr	61.00	43309.90	61.00	43309.90
Total For Both Units			**263,213.89**		**320,162.80**
Total Per Individual Unit			**131,605.95**		**160,081.40**

Source: Created by the authors

Table IV. Participants views on the prospects of stilt housing

Prospects	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Ranking**
P1: A stilted house could stop flooding damage if high enough off the ground.	2	5	4.04	.980	2
P2: The space underneath the house is useful for storage	2	5	3.85	1.099	3
P3: The space underneath the house is useful for parking cars out of the rain and off the road	2	5	4.22	1.050	1
P4: The increase in floor area would make the house more cost effective	1	5	3.56	1.121	7
P5: The increase in floor area would make the house of better value for the buyer	1	5	3.85	1.099	3
P6: The raised elevation of the stilted house would keep out insects and vermin such as mosquitos	1	5	2.78	1.050	9
P7: Stilt housing is worth the extra construction time and costs	1	5	3.33	1.177	8
P8: It should be standard for stilt houses to be made in flood prone areas	1	5	3.70	1.353	5

P9: Stilt housing has hazards and problems to consider when constructing or in use	1	5	3.63	.884	6
Valid N (listwise)					

N=27; Strongly Disagree=1; Strongly Agree=5

Source: Created by the authors

Table V. Participants' views on percentage increase in cost with the addition of stilts

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	< 10%	2	7.4	7.4	7.4
	10 – 20%	16	59.3	59.3	66.7
	20 – 30%	5	18.5	18.5	85.2
	30 – 40%	4	14.8	14.8	100.0
	Total	27	100.0	100.0	

Source: Created by the authors

How Editor's and Reviewer's Comments Were Addressed **Manuscript ID: JEDT-08-2023-0376.R3**		
	REVIEWER 1	
1	**Comments**	
	Line 196-199: Add a few more details on how stilt housing contributes to seismic resistance to support their potential for seismic resistance. Like you did for flood resistance and building on river and coastal regions and building on slopes.	Thank you for your comments. Some additional information has been included to better clarify how stilt housing enhances seismic resistance. Please refer to ***Page 5 (Lines 197-205).***
	Line 213: You indicated "the former's proficience in achieving thermal comfort". Rather than just a mere mention, expand on this a bit - for example what the paper said about stilt housing and thermal comfort - to demonstrate the potential for thermal comfort.	Thank you for your comments. Some additional information has been included to elaborate on how stilt housing enhances thermal comfort. Please refer to ***Page 5 (Lines 223-232).*** Similarly, some additional details have been added to expand how Stilt housing presents a practical solution for building on slopes. ***Please refer to Page 6 (Lines 256-264).***
	Check line 410 - (convenience sampling) and lines 433, 434 - (stratified sampling). You may need to reconcile your sampling techniques. As it is, it seems as if convenience sampling was the chosen technique. But because of sampling convenience and responses, the participants spread across the AEC professional hence the stratification/ spread across the professional spectrum. If this is not the case, then clarify that the convenience sampling targeted professionals that had already been stratified/ classified in predetermined AEC professional groups. Hence the use of both sampling techniques was intentional from the beginning.	Thank you for your comments. The authors clarified that the convenience sampling focused on professionals who were already stratified into predetermined groups of AEC professionals. ***Please refer to Page 10 (Lines 446-448) and Page 1 (Line 14).***
	Additional Questions:	
	Originality:	
2	Yes, it does.	Thank you for your comments.
	Relationship to Literature:	
3	Yes, it does.	Thank you for your comments.
	Methodology:	
4	Yes.	Thank you for your comments.
	Results:	
4	Yes.	Thank you for your comments.

	Implications for research, practice and/or society:	
5	Yes.	Thank you for your comments.
	Quality of Communication	
6	Yes.	Thank you for your comments.
	REVIEWER 2 COMMENTS	
	Comments	
1	The paper compares the cost of stilt and conventional housing using 5D BIM approach. The paper is generally good. Further, the author has made several revisions to the references but still lacks consistence.	Thank you for your comments.
	Additional Questions:	
	Originality:	
2	Yes. The paper is novel and has practical application.	Thank you for your comments.
	Relationship to Literature:	
3	Yes. The paper demonstrates understanding of literature on elemental cost analysis using 5D BIM approach.	Thank you for your comments.
	Methodology:	
4	Yes. Use of 5D BIM Cost estimating approach is good and timely.	Thank you for your comments.
	Results:	
7	Yes. The paper compares stilt and conventional housing in terms of elemental cost. Results have been clearly presented.	Thank you for your comments.
	Implications for research, practice and/or society:	
8	Yes. the paper definitely contributes to the body of knowledge as it compares stilt and conventional housing using 5D BIM approach.	Thank you for your comments.
	Quality of Communication:	
9	Yes. but can be improved.	Thank you for your comments. This concern has been addressed.

We appreciate the valuable comments provided by the reviewers. Their insights have been instrumental in enhancing the clarity and depth of our manuscript. We have carefully considered each suggestion and incorporated relevant revisions within the word count limit of the journal. The constructive feedback has undoubtedly strengthened the quality of our work. Thank you.