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Sustainability Study on Proposed Traditional Stilt House in Munshiganj as a Prefabricated Modular Housing Design

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Abstract

Bangladesh, highly susceptible to climate change, confronts significant housing difficulties stemming from disasters and rising urbanization, while traditional construction methods are expensive and rigid. In erosion-prone areas like as Munshiganj, conventional modular stilt houses constructed with timber, CI sheets, and elevated foundations provide a native adaptable solution. Their substantial prefabricated façade sections diminish efficiency and transportability. This study investigates a standardized 4′ × 8′ modular panel system that incorporates façade, window, and door elements to enhance material economy, cost-effectiveness, and scalability. Traditional and proposed systems were assessed by literature analysis, field surveys, material estimation, and cost comparison. Research demonstrates that an 8′ × 12′ unit necessitates just 10 panels, each utilizing 1.33 cubic feet of wood and one galvanized sheet, so decreasing panel weight by 50% and overall expenses by 18–24%. The compact, modular design improves mobility, durability, and sustainability for disaster-affected and economically disadvantaged housing situations.

Keywords: Sustainability; Traditional Stilt House; Prefabricated Modular House; Export Policy; Cost-Effectiveness.

1. Introduction

The worldwide housing deficit is exacerbated by swift urbanization, population increase, fluctuating economic circumstances, land scarcity, and elevated land costs, rendering economical dwelling progressively inaccessible for numerous individuals (Djukanovic et al., 2025). Concurrently, climate change and recurrent natural catastrophes have intensified the necessity for movable and versatile shelters (Perrucci et al., 2016). Conventional building techniques, marked by elevated expenses, labor intensity, and protracted schedules, are insufficient in meeting these changing demands (Gómez & Sánchez, 2024). As a result, modular housing has arisen as a sustainable, efficient, and adaptable option that facilitates expedited assembly, material efficiency, and quality assurance via prefabrication (Maceika et al., 2024). In accordance with sustainable design principles, modular systems reduce the utilization of carbon-intensive materials and enhance recyclability (Barbu & Bârsan, 2022). In Bangladesh, modular building is mostly unexamined, despite its considerable potential, especially in disaster-prone areas like Munshiganj. Communities in this region, often impacted by flooding and riverbank erosion, have historically constructed movable stilt dwellings from timber and corrugated iron sheets that can be disassembled and transported within hours (Billah, 2023). These vernacular practices demonstrate an intrinsic modular logic based on adaptation and resource efficiency. This research examines the sustainability and modular capabilities of traditional stilt homes in Munshiganj, analyzing how these indigenous structures might be standardized into prefabricated modular housing models that are climate-responsive, cost-effective, and relocatable in Bangladesh.

The present study addresses this opportunity by systematically examining how the vernacular modular logic embedded in Munshiganj stilt houses can be translated into a formally standardized, quantitatively evaluated prefabricated housing system. In doing so, this research contributes an original evidence base for the adoption of indigenous modular construction as a scalable, climate-responsive, and economically viable housing model for disaster-affected communities in Bangladesh.

1.1 Background

Bangladesh confronts persistent and escalating housing challenges driven by rapid urbanization, population growth, and the compounding effects of climate-related disasters. Annual flooding and riverbank erosion displace thousands of households each year, particularly in Munshiganj District, which lies at the confluence of the Padma and Meghna rivers and is among the most erosion-vulnerable regions in the country (Islam, 2007). Historical data indicate that riverbank erosion rates in parts of Munshiganj exceed 50 meters per year, resulting in the continuous loss of homes and agricultural land and the chronic displacement of riverine communities (Islam & Mitra, 2024). The scale of this crisis is considerable: between 2015 and 2021, over 7.5 million homes across Bangladesh were affected by flood and erosion events, while in the first months of 2024 alone, approximately 18.3 million individuals experienced displacement or housing loss (The Daily Star, 2024). Conventional construction methods, characterized by high material costs, extended build times, and dependence on skilled masonry labor, are structurally ill-suited to meeting the urgent, recurring, and economically constrained housing needs of these communities (Gómez & Sánchez, 2024).

In response to these conditions, communities in Munshiganj have developed a distinctive vernacular housing typology the traditional wooden stilt house that demonstrates a high degree of environmental and social adaptation. Constructed from locally sourced timber frames and corrugated iron sheet cladding, these lightweight structures can be disassembled and relocated within hours, providing a level of mobility and resilience that no conventional construction system can replicate (Billah, 2023). Research has further established that traditional wooden houses in Munshiganj exhibit higher social sustainability than contemporary masonry alternatives, owing to their cultural relevance, spatial adaptability, and alignment with the community's established patterns of domestic life (Bansal & Rezwan, 2022). Their dependence on local materials, capacity for component reuse, and inherent adaptability to seasonal flooding collectively exemplify an indigenous approach to sustainable construction that has evolved in direct response to environmental necessity. Modular housing systems have also been demonstrated to offer particular effectiveness in delivering affordable, high-quality shelter for low-income populations, with the cost efficiency and construction speed of prefabrication making such approaches a viable foundation for social housing provision (Nemer et al., 2025). This study examines the traditional stilt houses of Munshiganj as a paradigm for prefabricated modular housing, integrating vernacular construction knowledge with contemporary modular design principles to develop a scalable, climate-responsive housing model for disaster-affected communities in Bangladesh (Barbu & Bârsan, 2022; Maceika et al., 2024).Despite the long-standing presence of traditional stilt housing in flood-prone regions of Bangladesh, these vernacular systems remain informally constructed, dimensionally unstandardized, and architecturally undocumented. While indigenous communities in Munshiganj have organically developed lightweight, demountable timber structures capable of rapid assembly and relocation, these dwellings suffer from several critical limitations that constrain their scalability and broader applicability. Full-length prefabricated façade panels, often measuring up to 15 feet in length and weighing approximately 350 kilograms, present significant challenges in transportation, handling, and on-site installation (Billah, 2023). The dependence on imported hardwoods such as Azobe further increases construction costs and undermines economic accessibility for low-income households. Additionally, the absence of a standardized modular framework prevents replication, quality control, and efficient material usage across different disaster-affected sites.

Contemporary modular housing research has advanced considerably in high-income and industrialized contexts, demonstrating measurable gains in cost reduction, construction speed, and environmental performance (Gómez & Sánchez, 2024; Maceika et al., 2024). The flexibility of modular designs allows for easy disassembly and relocation, making them ideal for temporary housing solutions or areas prone to natural disasters (Sanjun & Lihua, 2017). However, the integration of vernacular construction knowledge with formal modular prefabrication principles remains largely unexplored in the context of South Asian, and specifically Bangladeshi, housing systems. Existing studies on disaster-resilient housing in Bangladesh predominantly address post-disaster relief through temporary shelter provisions rather than examining how indigenous building practices can be systematically transformed into scalable, permanent modular housing models (Perrucci et al., 2016; Kusbiantoro et al., 2024). This gap represents a significant missed opportunity, as the traditional stilt houses of Munshiganj already embody core modular principles demount ability, lightweight construction, and material reusability yet lack the dimensional consistency and technical standardization necessary for wider deployment. Furthermore, no documented quantitative framework currently exists for evaluating the material economy, transportation logistics, and cost-effectiveness of a standardized panel-based modular system derived from Bangladeshi vernacular housing typologies. Without such a framework, policymakers, architects, and disaster management agencies lack an evidence base for adopting indigenous modular housing as a viable, reproducible solution for climate-displaced populations.

1.1.1 Research Gap

Although substantial literature exists on modular and prefabricated housing systems globally, three specific and interrelated gaps can be identified in relation to the present study. First, modular housing research in South Asia, and Bangladesh in particular, remains nascent, with most studies focusing on urban apartment construction rather than rural, climate-vulnerable, or disaster-displaced communities (Djukanovic et al., 2025; Barbu & Bârsan, 2022). Second, while vernacular architecture scholarship has documented the spatial and material characteristics of traditional stilt housing in Bangladesh, no study has attempted to translate these indigenous building logics into a formally standardized prefabricated system with quantifiable performance metrics. Third, existing post-disaster housing frameworks in Bangladesh operate primarily through external aid models and imported construction technologies, overlooking the potential of locally rooted, community-familiar building systems to provide faster, more culturally appropriate, and economically sustainable housing solutions (Kizilova, 2025; Kusbiantoro et al., 2024). This study directly addresses these three gaps by proposing, evaluating, and quantifying a standardized 4′ × 8′ modular façade panel system grounded in the vernacular construction practices of Munshiganj.

1.1.2 Research Questions

This study is guided by the following research questions:

RQ1. What are the structural, material, and spatial characteristics of traditional modular stilt houses in Munshiganj, and to what extent do they embody the principles of prefabricated modular construction?

RQ2. How can a standardized 4′ × 8′ modular façade panel system be developed from the vernacular building logic of Munshiganj stilt houses to improve material economy, transportability, and ease of assembly?
RQ3. What are the measurable differences in construction cost, labor requirement, material consumption, and transportation efficiency between the traditional stilt house system and the proposed standardized modular panel system?
RQ4. To what extent does the proposed modular housing system meet the environmental, economic, and social sustainability criteria required for deployment in climate-vulnerable and disaster-affected communities in Bangladesh?

2.Literature Review

Modular construction has gained substantial scholarly and industry attention as a viable alternative to conventional building methods, with documented performance advantages spanning cost efficiency, construction speed, and environmental impact. Gómez and Sánchez (2024) demonstrate that modular techniques achieve a 35% reduction in project duration and 22% lower costs compared to traditional approaches, completing equivalent projects in approximately 10 months rather than 15.5 months at roughly $120 per square foot against $154. Resource efficiency gains are equally significant; modular systems have been shown to reduce water consumption by 30%, gas usage by 80%, and utility expenditure by 25% relative to conventional construction baselines (Hodbe & Sober, 2019; Albaadani et al., 2025). The structural logic underpinning modular construction emphasizing lightweight components, reduced reliance on concrete and steel, and minimal foundation requirements inherently lowers embodied carbon and facilitates component removal, reuse, and end-of-life recyclability, positioning modular housing as a fundamentally more sustainable construction paradigm than its conventional counterpart. The integration of locally available materials further strengthens this sustainability case; in Hargotirto Village, Indonesia, timber and bamboo have been successfully employed in temporary modular shelter design, leveraging existing local craftsmanship skills to enable rapid, efficient construction while simultaneously supporting regional economies, reducing dependence on imported materials, and fostering community ownership of the built outcome (Christian & Feriadi, 2022; Dacto et al., 2025).

The global applicability of modular strategies to complex social and environmental challenges has been demonstrated across diverse cultural and geographic contexts. Shigeru Ban's Paper Tube Shelter system exemplifies how rapid-assembly, low-cost modular components can provide dignified emergency housing for disaster survivors with minimal material resources (Miyake, 2009). Adeyemi et al. (2024) further establish that the inherent scalability and dimensional consistency of modular design enable significant cost reductions and accelerated deployment timelines in humanitarian housing contexts. In Nigeria, architect Blossom Eromosele developed a modular housing typology rooted in traditional African spatial and formal principles to address the shelter needs of over 3.2 million internally displaced persons, demonstrating that modular systems can simultaneously serve humanitarian, cultural, and architectural objectives (Piñeiro, 2025). Similarly, Kusbiantoro et al. (2024) developed folding modular shelter units in Indonesia specifically designed to enhance post-disaster resilience, confirming the adaptability of modular construction logic to varying site conditions and community requirements. Collectively, these precedents establish that well-designed modular systems are capable of integrating cultural identity, operational efficiency, and ecological responsibility within a single coherent framework.

The environmental credentials of prefabricated modular construction have been further substantiated through comparative lifecycle assessments. Moradibistouni et al. (2019) found that prefabrication consistently outperforms traditional construction in terms of water consumption and construction waste generation, though differences in energy use and atmospheric emissions are less definitive and remain context-dependent. The capacity of modular approaches to accommodate customization and local adaptation has been identified as a critical determinant of their social sustainability; Rahubadda and Thurairajah (2025) emphasize that modular systems which meaningfully integrate local material knowledge and community-specific spatial requirements are significantly more likely to achieve long-term occupant acceptance and cultural relevance than externally imposed standardized solutions. The use of locally available materials and reusable panel molds in modular construction further reduces environmental impact across the supply chain while supporting regional sustainability objectives in line with broader circular economy principles (Gonidakis et al., 2025).

Bangladesh's indigenous riverine housing typologies particularly the traditional stilt dwellings of Munshiganj exhibit several characteristics that align closely with contemporary modular construction principles. Lightweight timber structural frameworks, demountable corrugated iron sheet cladding systems, and elevated stilt foundations combine to produce dwellings that are mobile, economically accessible, and climatically responsive to the flooding and erosion conditions of the region (Billah, 2023; Huda, 2020). These structures can be disassembled and relocated within hours, demonstrating a level of operational flexibility that many formally designed modular systems aspire to but rarely achieve in practice. The social and cultural embeddedness of these vernacular dwellings within Munshiganj communities further distinguishes them from externally developed housing solutions, as local artisans possess the skills, tools, and material knowledge required to construct, maintain, and adapt these structures without external technical assistance. Nevertheless, the construction of these dwellings remains informal and dimensionally unstandardized, limiting their scalability, replicability, and integration into formal housing supply chains and disaster relief frameworks.

Despite these global advances, a critical gap persists in the literature concerning the formal standardization of vernacular modular housing in South Asia. The traditional stilt dwellings of Munshiganj represent an underexplored typology that inherently satisfies many modular construction principles, yet has received no systematic academic treatment in terms of dimensional standardization, material quantification, or cost modeling. This study addresses that gap directly, positioning vernacular construction knowledge as both a valid starting point and a culturally grounded foundation for contemporary prefabricated housing design in climate-vulnerable contexts.

2.1 Aim and Objective
The research is to examine the sustainability and modular capabilities of traditional wooden stilt homes in Munshiganj and to create a prefabricated modular housing solution that improves affordability, resilience, and flexibility for climate-vulnerable people in Bangladesh.

The project's objectives include
1. To record and examine the design rationale, building methodologies, and material applications of current modular wooden stilt dwellings in Munshiganj.
2. To provide a standardized modular façade panel system that enhances material economy, transportability, assembly, and scalability.
3. To assess the economic viability of the proposed system by conducting a comparative study of costs, labor, and materials between traditional and modular models.

3. Materials and Methods
This study adopted a descriptive-analytical research methodology integrating both qualitative and quantitative approaches within a structured three-phase framework, as illustrated in Figure 1.

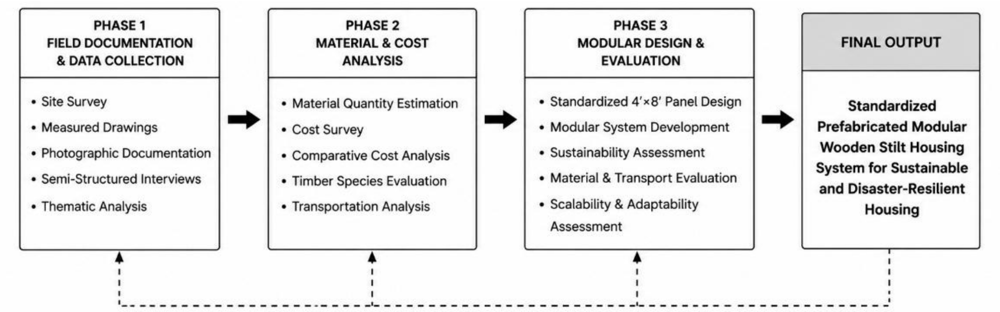

Figure 1. Research methodology (Developed by the Authors).

Phase 1- Field Documentation and Data Collection. Primary data were collected through systematic field surveys conducted in Munshiganj District, Bangladesh. Site visits were undertaken to document the spatial configuration, structural assembly, material composition, and joinery details of existing traditional wooden stilt houses. Photographic documentation and measured drawings were produced for a representative sample of structures. Semi-structured interviews were conducted with local carpenters, homeowners, and building contractors to gather experiential knowledge regarding construction rationale, material sourcing, assembly sequences, and cost practices. Interview responses were recorded, transcribed, and analyzed thematically to identify recurring patterns and critical limitations in current construction practice.
Phase 2- Quantitative Material and Cost Analysis. Based on field data, material quantities were computed for a standard existing unit measuring 8′ × 15′, including wood volume in cubic feet (CFT), number of corrugated iron sheets, and associated labor and transportation costs. A comparative material estimation was subsequently conducted for a proposed modular unit measuring 8′ × 12′, based on the standardized 4′ × 8′ panel system. Cost data were sourced from local market surveys and verified through builder interviews. Comparative cost tables were developed to quantify savings in material consumption, labor, and transportation between the traditional and proposed systems. Locally available timber species — including Koroi, Mahogany, Garjan, Azobe, and Eucalyptus - were evaluated against criteria of structural performance, durability, availability, and cost-effectiveness.
Phase 3 - Modular System Design and Evaluation. A standardized 4′ × 8′ modular façade panel system was developed using the dimensional logic derived from field analysis and aligned with international modular grid standards. The panel design integrates façade, window, and door components into a single manageable unit. The system was evaluated against criteria of material economy, ergonomic handling, transportability, scalability, and adaptability. Sustainability was assessed across environmental, economic, and social dimensions using a structured indicator-based framework. The entire methodology was designed to ensure that findings are replicable, evidence-based, and directly applicable to housing policy and architectural practice in disaster-prone regions of Bangladesh.

4. Results
4.1 Existing Construction Practices
Traditional modular wooden houses in Munshiganj are predominantly single- or two-storied, constructed on short RCC or bamboo stilts (about 2 feet high) to mitigate floods. The superstructure comprises locally sourced timber and corrugated iron sheets. Columns are affixed to the RCC foundation using metal plates for convenient disassembly. Construction is finalized within 7 to 10 days in workshops and installed on-site within 2 to 4 days. An 8 ft × 15 ft unit utilizes roughly 49.34 cubic feet of wood for construction, doors, and windows. The cost ranges from BDT 250,000 to 300,000, contingent upon the type of wood and finish. Nonetheless, substantial one-piece façade panels augment weight (up to 350 kg per wall), complicating shipping and elevating costs. These structures exhibit partial prefabrication; yet, they lack modular segmentation, which constrains scalability and transport efficiency. Field data and builder interviews revealed three primary structural methods utilized in the stilt buildings of Munshiganj, as illustrated in Table 01 and Figure 01,02,03.

Table 01. Existing construction practice (Source: Authors).

Component	Traditional System	Materials Used	Joinery Type	Remarks
Foundation	Raised stilt base	Timber/Bamboo	Peg/Nail Joint	Prevents flood damage
Frame	Rectangular timber frame	Local wood (Mahogany, Koroi, Meghni)	Mortise-tenon / Bolt	Reusable and portable
Wall & Roof	CI sheet panels	Corrugated iron or bamboo mat	Nailed/Fitted	Lightweight and replaceable


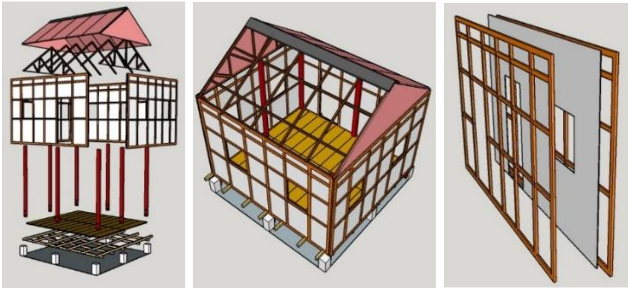

Figure 01. Exploded 3D model of existing building by components (Source: Authors).
Figure 02. Axonometric view of existing modular house, Munshiganj (Source: Authors).

Figure 03. The modular façade panels layer- wooden main frame, galvanized plain sheet, curved wooden planks; Modular houses being shifted in crisis moment (Source: Derived from local news).

Field documentation revealed that while the traditional stilt house system demonstrates intuitive modular principles including prefabrication at workshop level, use of lightweight local timber, and demountable joinery the system lacks dimensional standardization. The full-length façade panels, typically measuring 8′ × 15′ and weighing between 170 to 350 kilograms depending on timber species, represent the most critical constraint on transportability and scalability. This finding directly motivated the development of the proposed 4′ × 8′ standardized panel system presented in Section 3.2.

4.1.1 Material Specification and Cost Estimation

Diverse timber species are chosen based on client preferences and financial constraints. Koroi wood is frequently utilized for flooring, has a lifetime of 15 to 20 years. Azobe, sometimes referred to as Loha wood, is a solid imported hardwood from West Africa utilized for basic structural components like posts and beams, with a lifespan of up to 100 years. Locally sourced eucalyptus (deshi loha) has an estimated lifespan of around 50 years, whilst mahogany is utilized for flooring planks. Bilinga wood is commonly utilized in the construction of doors and window frames. The typical proportions of a home are around 8 feet by 15 feet. The outside walls are clad with unadorned galvanized sheets, while the roofing is comprised of CI sheets, occasionally supplemented with insulation to mitigate heat absorption. Workshop fabrication necessitates 7 to 10 days, succeeded by 2 to 4 days for on-site assembly. Construction expenses vary from BDT 2–4 lakh based on the type of timber utilized. Labor, transportation, and material selection substantially affect the ultimate cost (Table 02).

Table 02. Estimation of the materials per unit (Source: Author).

Material name	Unit	Cost per unit (Taka)
Azobe wood (Loha wood)	cft	3000-3500
Koroi wood	cft	500-600
Eucalyptus wood (Deshi Loha)	cft	1200-1500
Mahogany wood	cft	1500-2000
Bilinga	cft	3500

Corrugated iron sheet (CI) 0.32mm dhew tin	One bundled	7050
Galvanized plain sheet	kg	145
Screw, nails, bolts	kg	--

Despite being built with simple tools, these structures achieve structural stability with low material consumption. However, durability issues arise due to untreated timber and non-standardized sizing. Improving this through modular penalization could extend lifespan and allow precision fitting.

A comparative wood volume analysis between the traditional 8′ × 15′ unit and the proposed 8′ × 12′ modular unit reveals that the proposed system requires approximately 30–35% less total timber volume, primarily due to the elimination of redundant framing members made possible by the standardized panel grid. This reduction directly translates into lower material cost, reduced transportation load, and decreased construction waste, supporting the environmental sustainability goals of the proposed system.

4.1.2 Proposed Modular Panel System

Using conventional reasoning, the research project aimed to produce a standardized facade panel system that measures 4 feet by 8 feet. This particular dimension is in accordance with both the regional material requirements and the worldwide modular grids, which guarantees compatibility and scalability. The majority of the time, local artisans construct full-length wall panels that function more like prefabricated facades than they do as genuine modular components. In addition to being difficult to carry and labor-intensive to install, these huge panels, which generally measure 15 feet and 8 feet in length and weigh around 350 kilograms and 170 kilograms respectively (using Loha wood frames and GI sheet infills), are also challenging to transport. In order to overcome these limits, the research presents a modular facade panel measuring 4 feet by 8 feet. This panel is produced using the same process, but it is constructed in manageable sections. By utilizing this standardized approach, the flexibility, transportability, and convenience of assembly are enhanced, hence enabling scalable designs. For instance, a home measuring 8 feet by 12 feet may be constructed using ten modules (Table 03, Figure 04, Figure 05).

Table 03. Proposed modular system (Source: Authors).

Feature	Traditional House	Proposed Modular System
Panel Size	Variable	4′ × 8′ standardized
Material	Local and exported timber, galvanized sheet	Treated mahogany + galvanized sheet
Assembly Time	5–7 days	2–3 days
Dismantling Time	1-2 days	Approx. 1 day
Transportability	Moderate	High (modular units)

Figure 04. Proposed 4’/8’ modular wooden panel and the growth of the incremental house (Source: Authors).

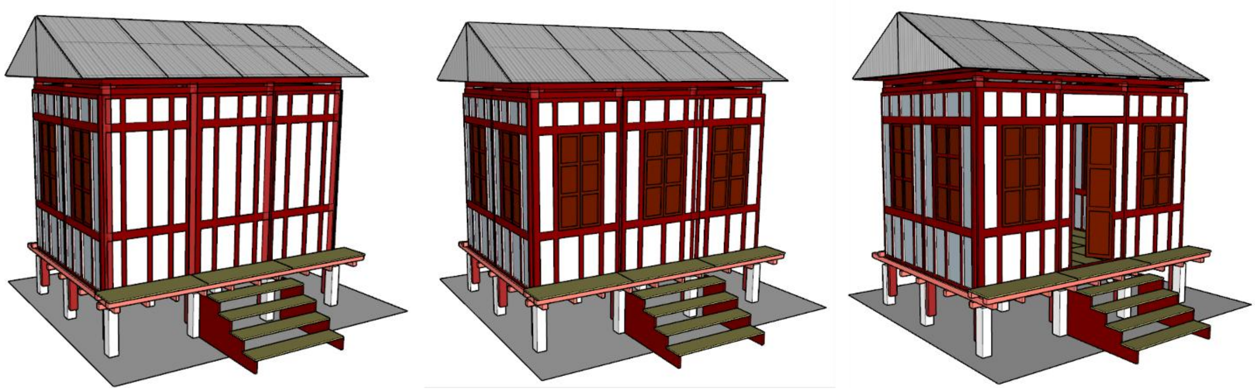

Figure 05. Proposed 4'/8' modular panels and the variation possibilities of facade (Source: Authors).

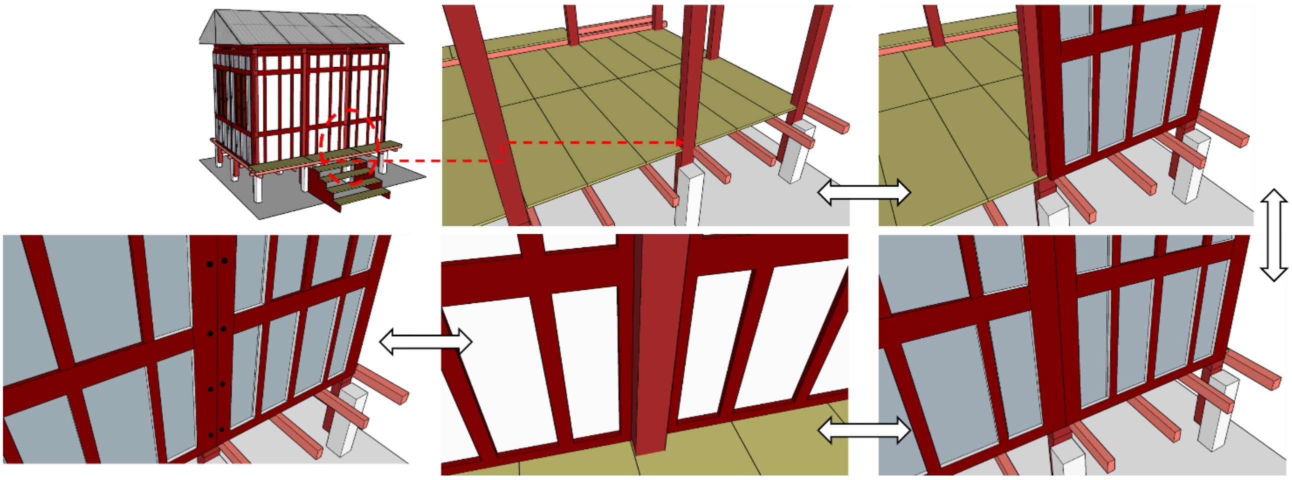

Figure 06. Proposed 4'/8' modular panels and the panel installation in wooden post (Source: Authors).

The comparative analysis in Table 03 and the depicted modular panel configuration (Figures 02 and 03) illustrate the practical viability of the standardized 4′ × 8′ system in minimizing panel weight, augmenting transportability, and improving assembly efficiency, thus creating a scalable framework for adaptive modular housing development. The forthcoming part will present the results, discussion, and benefits of the proposed design

The 4′ × 8′ panel dimension was selected on the basis of three convergent criteria: alignment with standard galvanized iron sheet dimensions available in local Bangladeshi markets, compatibility with international modular grid standards of 1200mm × 2400mm, and ergonomic handleability by two workers without mechanical lifting equipment. An 8′ × 12′ house unit requires exactly 10 panels ,4 wall panels per long side, 1 panel per short side producing a dimensionally consistent, arithmetically simple assembly logic that minimizes site-level decision-making and reduces skilled labor dependency.

4.2 Proposed Modular Panel System

4.2.1 Comparative Analysis — Traditional vs Proposed System

To quantitatively evaluate the performance of the proposed modular system against the traditional construction method, a structured comparative analysis was conducted across four dimensions: material consumption, construction cost, assembly time, and transportation efficiency. The results are summarized in Table 04.

Table 04. Comparative performance analysis: Traditional vs proposed modular system (Source: Authors).

Parameter	Traditional System (8′×15′)	Proposed Modular System (8′×12′)	Improvement
Total Wood Volume	~49.34 CFT	~32–34 CFT	~30–35% reduction
Panel Weight (per wall)	170–350 kg	85–90 kg	~50% reduction
Construction Cost	BDT 2,50,000–3,00,000	BDT 1,90,000–2,40,000	18–24% reduction
Workshop Fabrication Time	7–10 days	4–5 days	~40% reduction
On-site Assembly Time	2–4 days	1–2 days	~50% reduction
Number of Workers Required	6–8	3–4	~50% reduction
Transportability	Moderate — requires large truck	High — fits standard pickup	Significantly improved
Material Reusability	Partial	High — full panel reuse	Substantially improved

The data presented in Table 04 confirm that the proposed modular system outperforms the traditional construction method across all evaluated parameters. The most significant gains are observed in panel weight reduction and on-site assembly time, both of which directly address the primary constraints identified during field documentation. These findings validate the central hypothesis of this study that the standardization of vernacular modular logic through a dimensionally consistent panel system produces measurable improvements in construction efficiency, cost-effectiveness, and scalability.

4.2.2 Panel Weight and Material Economy

A detailed weight analysis of the proposed 4′ × 8′ panel was conducted based on material specifications derived from field surveys. Each panel comprises one Koroi wood frame consuming approximately 1.33 CFT of timber and one galvanized plain sheet weighing approximately 8–10 kg. The total panel weight is estimated at 85–90 kg, compared to 170–350 kg for traditional full-length panels. This 50% weight reduction enables two workers to handle, transport, and install each panel without mechanical assistance, significantly reducing labor costs and enabling deployment in remote riverbank and char areas accessible only by boat or small vehicle. From a material economy perspective, the standardized 4′ × 8′ grid eliminates the dimensional variability inherent in traditional construction, where panels are cut to fit individual structures without reference to a common module. Standardization enables bulk pre-cutting of timber members to consistent lengths, reducing off-cut waste by an estimated 15–20% and allowing unused panels from one structure to be directly reused in another without modification.

5. Discussion

5.1 Advantages of Proposed Modular Façade Panel System

The proposed modular building concept, initially designed for areas susceptible to river erosion, possesses potential applications that transcend just emergency or temporary housing situations. The method provides several long-term benefits relevant to both rural and urban environments. This housing model's primary strength lies in its robust connection with the principle of incremental housing. The house's minimum foundation need and lightweight structure facilitate progressive expansion over time, accommodating the evolving demands of its occupants. This renders the system especially appropriate for families whose spatial and functional needs change over time (Figure 07).
The modular design of the panels facilitates adaptable expansion, from minor augmentations to significant spatial alterations. New rooms or functional areas can be included without disrupting the existing framework, hence minimizing construction complications and circumventing total demolition or reconstruction. When certain panels are not needed temporarily, they may be removed and stored, transferred to another area, or repurposed for a new project. This attribute effectively enhances material reusability and facilitates a circular building methodology. This flexibility closely mirrors the organic development of rural homesteads in Bangladesh, where residences incrementally enlarge in response to familial expansion, economic advancement, or functional requirements. The suggested modular panel system provides a streamlined and systematic approach for gradual development, avoiding complexity and construction burdens at each expansion step.

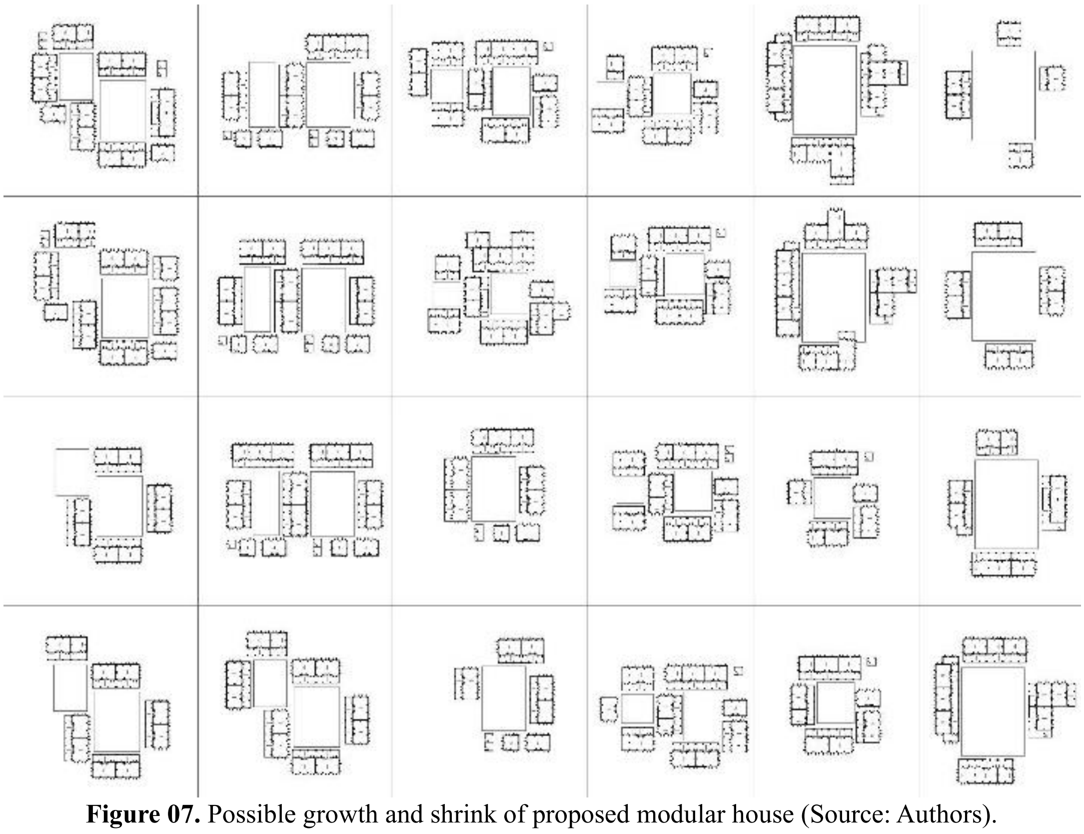

Figure 07. Possible growth and shrink of proposed modular house (Source: Authors).

This homestead demonstrates a continuous cycle of incremental growth and shrinkage, where spaces are added, removed, and reused over time according to changing family needs, economic conditions, and environmental factors rather than following a fixed permanent construction model. Therefore, beyond fast assembly, disassembly, and transportation efficiency, the system functions as a flexible housing framework that responds to diverse use patterns, long-term occupancy, and evolving lifestyles, making it equally relevant for permanent settlements in mainland areas as well as vulnerable riverine regions.

5.1.1 Economic and Environmental Assessment

According to cost research and literature (Hodbe & Sober, 2019; Maceika et al., 2024), modular building provides 20–25% cost savings and a 30–40% decrease in time compared to traditional brick-concrete houses. Locally produced lumber diminishes embodied carbon and bolsters local economy. Table 05 presents a comparison of the building costs and logistics of typical brick houses vs the suggested modular timber houses.

Table 05. Economic comparison between traditional house and modular wooden houses (Source: Authors).

Parameter	Traditional Brick House	Modular Wooden House
Construction Cost (per 100 sqft)	1,200–1,500 USD	800–1,000 USD
Construction Time	30–45 days	15–20 days
Labor Requirement	Skilled (masonry)	Semi-skilled (carpentry)
Material Reusability	Low	High
Environmental Impact	High (cement, brick kiln)	Low (renewable materials)

Modular timber houses provide an eco-friendly alternative to concrete and steel structures by utilizing renewable, low-carbon resources. Locally sourced timber and traditional joinery mitigate carbon emissions throughout the construction lifetime, while wood's inherent capacity to sequester CO_2 further diminishes the carbon footprint. Prefabrication guarantees optimum material use, low waste generation, and less on-site interruption.

Engineered for reusability and recyclability, modular components adhere to circular building principles, prolonging material lifespan and reducing landfill effect. In flood-prone areas such as Munshiganj, elevated modular homes improve ecological resilience by facilitating natural drainage and minimizing land disruption. This methodology integrates traditional craftsmanship with modular innovation to provide low-carbon, flexible, and sustainable housing for Bangladesh's climate-responsive future. The assessment of sustainability outcomes for the proposed design is given in Table 06.

Table 06. Sustainability assessment of the project (Source: Authors).

Dimension	Indicators	Assessment	Sustainability Outcome
Environmental	Renewable materials, waste reduction	High	Lower embodied energy, reusable modules
Economic	Cost, labor, transport efficiency	High	Affordable, job-generating, low maintenance
Social	Adaptability, community resilience	Very High	Supports relocation, customization, family growth

The environmental benefits of the proposed system extend beyond material efficiency. The use of locally sourced Koroi and Mahogany timber reduces the embodied carbon associated with long-distance material transportation, which is a significant but frequently overlooked component of construction-related emissions in rural Bangladesh. Furthermore, the modular panel system's compatibility with traditional joinery techniques mortise-tenon connections and bolt fastenings rather than adhesives or composite materials ensures that all components remain fully separable at end of life, supporting a circular material economy in which individual panels can be dismantled, repaired, and redeployed across multiple building cycles.

5.1.2 Transportation Advantages

Transportation is essential in the construction and removal of modular wooden stilt dwellings in Munshiganj. The portability and demountability of these structures enable the efficient transportation of building components from sawmills to construction sites or between places post-dismantling, which is a key feature of their modular sustainability (Table 07). Field studies indicated that the majority of structural components, including timber columns, beams, façade panels, and roof frames, are prefabricated at local carpentry workshops. The prefabricated components are subsequently conveyed to the site using small to medium-sized pickup trucks or locally accessible boats, contingent upon accessibility and closeness to the river. The modular design of the components facilitates human manipulation, minimizing labor expenses and energy usage.

Table 07. Transportation Expenses (Source: Authors).

Transport Mode	Capacity	Typical Use	Approximate Cost (BDT)
7-ft Pickup (1 ton)	Small house components	Local transport within Munshiganj	1,000–2,000
9-ft Pickup (1.5 ton)	Full house module sets	District-level transport	2,000–3,500
12-ft Pickup (2 ton)	Multi-house delivery or larger modules	Long-distance (Munshiganj–Dhaka)	4,000–6,000
River Boat (Local ferry or cargo)	0.5–2 ton	Riverbank or char area access	500–1,000 (depending on distance)

The lightweight characteristics of materials, mostly lumber and corrugated tin, enable efficient loading and unloading. Elements like wall panels and roof trusses are frequently secured and arranged to optimize space, enabling a single pickup truck to transport the materials for a complete 15′ × 8′ house in one journey. Transportation expenses are comparatively little and increase with distance rather than weight, rendering it economically viable even for low-income individuals. In Munshiganj, standard transport fees vary from BDT 1,000 to 2,000, whilst delivery to Dhaka incurs prices ranging from BDT 1,500 to 6,000, contingent upon the size of the residence and the route used. Supplementary fees may be incurred for ferry crossings and tolls, particularly when across the Padma River or reaching distant islands (chars). The amalgamation of river and road transport networks markedly improves the system's flexibility, enabling these modular parts to be swiftly repositioned in reaction to river erosion, floods, or population displacement. This logistical adaptability enhances the sustainability and resilience of the housing model, rendering it appropriate for deployment in disaster-prone, rural, and peri-urban areas throughout Bangladesh.

5.1.3 Summary of the Discussion

The research encompassed thorough documenting and analysis of current modular wooden stilt buildings in Munshiganj to comprehend their structural, material, and spatial principles. Field surveys, comprehensive drawings, measurements, and photographic documentation were executed to document construction methodologies, joinery specifics, and façade configurations. Interviews with local carpenters, homeowners, and builders yielded insights into prevailing methods, constraints, and the socio-economic factors shaping design decisions. These evaluations found critical problems, including huge prefabricated panels, reliance on expensive imported lumber, and a lack of dimensional uniformity, all of which constrain mobility, price, and scalability. The research offered a standardized 4′ × 8′ modular façade panel system, optimized by material dimensioning, ergonomic handling, and transport analysis to solve these challenges. The economic viability was evaluated using a comparative cost study, focusing on wood volume (CFT), labor requirements, and transportation expenses comparing current and planned methods. The findings demonstrated savings of 18–24% in the modular architecture, mostly attributable to decreased material use and streamlined assembly processes. The study assessed the structural and economic viability of indigenous timber species, including Koroi, Mahogany, and Garjan, affirming their promise as sustainable and cost-effective substitutes for imported hardwoods. The research ultimately revealed the system's capabilities for flat-packing, reusability, and flexibility, establishing modular wooden housing as a feasible, economical, and durable construction method for disaster-prone and resource-limited areas in Bangladesh.

5.2 Achievement of the Project

The research project designed and assessed a standardized 4′ × 8′ modular façade panel system as a cost-efficient, scalable, and climate-responsive housing option, drawing inspiration from the traditional wooden stilt homes of Munshiganj. Field investigations recorded indigenous design rationale, joinery methods, and material use, demonstrating how artisans instinctively employed modular principles with moveable timber frames and stilt foundations to accommodate floods. Significant hurdles in current techniques, such as cumbersome full-length panels, dependence on imported hardwoods, and transportation issues, underscore the necessity for uniformity. The suggested modular design incorporates façade, window, and door components, utilizes locally sourced timber (Koroi, Mahogany, Garjan), and accomplishes a 50% decrease in panel weight along with 18–24% cost reductions. The research created a quantitative framework for material, labor, and transportation costs, showing economic viability and scalability. The research advocates for the utilization of local timber and modular design, hence endorsing sustainability, circular economy principles, and robust architecture against disasters. It integrates traditional knowledge with contemporary prefabrication, providing a flexible, cost-effective, and exportable modular housing solution for at-risk populations.

5.3 Limitations of the Study

While this study provides a substantive empirical and analytical foundation for the proposed modular housing system, several limitations must be acknowledged. First, the cost and material data presented are derived from field surveys conducted within Munshiganj District and reflect local market conditions as of the survey period; these figures may vary across different regions of Bangladesh or over time due to fluctuations in timber prices and material availability. Second, the structural performance of the proposed 4′ × 8′ panel system under dynamic loading conditions including flood-induced hydrostatic pressure, wind uplift, and seismic forces has not been formally tested in this study. The current evaluation is based on qualitative assessment and material precedents from existing vernacular practice rather than laboratory or computational structural analysis. Third, the study does not address the long-term durability performance of untreated locally sourced timber under the high humidity and cyclical wetting conditions characteristic of Munshiganj's riverine environment. Future research incorporating accelerated weathering tests and preservative treatment trials would substantially strengthen the evidence base for the proposed system. These limitations notwithstanding, the findings of this study constitute a significant and original contribution to the fields of vernacular architecture, modular construction, and disaster-resilient housing design in Bangladesh.

5.4 Implication for Policy and Practice

The findings of this study carry direct implications for housing policy, disaster management planning, and architectural practice in Bangladesh. At the policy level, the demonstrated cost-effectiveness and material efficiency of the proposed modular system suggest that government-led post-disaster housing programs currently dominated by imported prefabricated components or conventional brick-concrete construction could achieve substantially greater reach and impact by incorporating locally derived modular timber systems. The 18–24% cost reduction documented in this study translates, at scale, into a meaningful increase in the number of households that can be assisted within a fixed relief budget. For architectural practitioners and construction professionals, the study provides an actionable design framework the standardized 4′ × 8′ panel that can be immediately adopted within existing local carpentry infrastructure without requiring new tools, machinery, or imported materials. The system's compatibility with traditional joinery skills means that local artisans can produce and assemble the proposed panels with minimal additional training, preserving livelihoods while improving housing outcomes. At the community level, the incremental growth and shrinkage capability of the modular system aligns directly with the lived realities of Munshiganj households, whose spatial needs fluctuate with family size, seasonal flooding patterns, and economic conditions. This adaptability makes the proposed system not merely a post-disaster intervention but a long-term housing strategy appropriate for permanent settlement in Bangladesh's most climate-vulnerable riverine districts.

5.5 Contribution to the Society

This study tackles a critical issue in Bangladesh: delivering inexpensive, flexible, and disaster-resistant housing for populations impacted by floods, river erosion, and displacement. This study integrates the traditional modular stilt houses of Munshiganj with a standardized 4′ × 8′ modular façade panel system, thereby merging indigenous knowledge with modern housing innovation to establish a model that is socially inclusive, environmentally sustainable, and economically feasible. The primary social impact is to housing resiliency and accessibility. The modular system is lightweight, portable, and reconfigurable, allowing for rapid assembly with minimum tools, hence facilitating speedy reconstruction, relocation, or expansion of homes during emergencies. This alleviates both economic and emotional strain, fostering a humanistic, community-oriented methodology. A further contribution is the rejuvenation and modernization of indigenous handicraft. The approach strengthens the skills, livelihoods, and agency of local craftsmen in Munshiganj by leveraging traditional joinery techniques and reducing reliance on nails and screws, so fostering employment, skill transfer, and cultural preservation. The project prioritizes the utilization of sustainable materials and circular building practices. Locally sourced timbers such as Koroi, Mahogany, and Garjan substitute imported hardwoods, hence diminishing expenses and carbon emissions. The reusability, dismantlability, and recyclability of modular components further reduce waste, in accordance with SDG 11 and SDG 12. The modular approach economically decreases building costs by 18–24%, facilitates shipping via flat-packing, and enables small-scale manufacturing and future export, therefore aiding low-income households and enhancing Bangladesh’s position in the worldwide prefabricated housing market. The technology promotes community engagement and inclusion, enabling users to customize layouts, façades, and materials based on their requirements and financial constraints. This user-centric methodology perceives housing as a dynamic process instead of a fixed product. The project illustrates that innovation may arise from tradition, transforming vernacular stilt buildings into a scalable, durable, and culturally rooted concept. It enables communities to adjust to climatic and economic risks while maintaining individuality and craftsmanship, offering a reproducible model for sustainable housing applicable to Bangladesh and other areas with analogous climate and relocation issues.

5.6 Future Scope

This research opens several future directions for developing and expanding the modular wooden housing system of Munshiganj. Subsequent efforts may concentrate on the structural and environmental evaluation of the modular façade panels to ascertain their stability under flood, wind, and load conditions. Enhanced joint details and the hybrid use of wood, bamboo, and jute panels can augment durability and flexibility. Future research may investigate alternate local materials, including engineered bamboo and agricultural by-products, as well as natural protective coatings for moisture and termite resistance. An examination of the lifecycle and carbon footprint will assist in validating its sustainability. The system may develop at the community level through participatory building methods, enabling local carpenters and households to create and modify modular modules with ease. Integrating digital manufacturing and parametric design technologies might provide adaptable layouts for various site situations. The technology shows potential for disaster-relief housing, temporary settlements, and exportable prefabricated units, positioning Bangladesh as a paradigm for sustainable modular building. The future involves enhancing, evaluating, and expanding the design to create a robust, cost-effective, and contextually appropriate housing system that addresses both local and global requirements.

Beyond technical refinement, future research should also investigate the policy and regulatory pathways required to formally recognize vernacular-derived modular housing systems within Bangladesh's national building code and disaster housing frameworks. Comparative studies examining analogous vernacular modular typologies in other riverine and deltaic regions of South and Southeast Asia including the Mekong Delta in Vietnam, the Brahmaputra floodplain in Assam, and the Irrawaddy Delta in Myanmar would further establish the global relevance and transferability of the model developed in this study.

6. Conclusions

This study demonstrates that the traditional wooden stilt houses of Munshiganj possess significant potential to serve as a sustainable foundation for contemporary prefabricated modular housing in Bangladesh. Through field documentation, material estimation, cost analysis, and modular design evaluation, the research identified the inherent adaptability, portability, and resource efficiency embedded within vernacular construction practices. Building upon these findings, the study proposed a standardized 4′ × 8′ modular façade panel system that integrates wall, window, and door components into a manageable prefabricated unit. Comparative analysis indicates that the proposed system can reduce material consumption, transportation complexity, and overall construction costs while improving assembly efficiency, scalability, and future expandability. The use of locally available timber further strengthens environmental sustainability by reducing embodied carbon and supporting local craftsmanship and supply chains. The research objectives were successfully achieved by documenting existing construction practices, developing a standardized modular panel system, and evaluating its economic and practical feasibility. The proposed framework demonstrates how indigenous architectural knowledge can be transformed into an evidence-based modular housing strategy suitable for disaster-prone and resource-constrained regions. The principal contribution of this study lies in bridging vernacular architecture with contemporary prefabrication technology through a replicable and context-sensitive design approach. Unlike conventional modular housing models, the proposed system preserves local construction logic while enhancing flexibility, affordability, and long-term sustainability. The findings provide valuable insights for architects, policymakers, and housing practitioners seeking climate-responsive and resilient housing solutions aligned with circular construction principles and sustainable development goals. Although the study primarily focuses on architectural, material, and economic aspects, future research should incorporate detailed structural testing, life-cycle assessment, thermal performance evaluation, and full-scale prototype validation under real environmental conditions. Such investigations would further strengthen the applicability of the proposed system for large-scale implementation. Overall, this research establishes that the modular transformation of traditional Munshiganj stilt houses offers a practical, affordable, and environmentally responsible housing model capable of addressing the growing demand for resilient and adaptable housing in Bangladesh and other climate-vulnerable regions.

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Conflicts of Interest
The Authors declares that there is no conflict of interest.

Data Availability Statement
The data in this work can be obtained from the corresponding author upon a reasonable request. The dataset comprises field survey records, measurement drawings, photographic documentation, and interview transcripts obtained from Munshiganj.

Institutional Review Board Statement
This study did not involve human participants, animal subjects, or sensitive personal data. Ethical approval was therefore not required. The research was conducted in accordance with applicable institutional and national guidelines.

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