Structural Adaptation and Sustainability of Bajo Architecture in Indonesia: A Meta-Analysis of Traditional Maritime Construction Innovations

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Abstract: The traditional architecture of the Bajo people in Indonesia represents an extraordinary manifestation of adaptation and sustainability developed over centuries in dynamic maritime environments. This meta-analysis synthesizes findings from 24 relevant scientific studies to identify common patterns, regional variations, and maritime construction innovations in Bajo architecture. The primary focus is on material types, construction techniques, adaptive solutions to marine environmental challenges (tides, waves, wind), and inherent sustainability principles. The results indicate a dominance of stilt houses built with local materials such as mangrove wood, posi-posi wood, ironwood, bamboo, sago palm, and nipa leaves. Structural innovations such as deep pile foundations, interlocking joinery systems, and adaptive roof designs ensure resilience against extreme conditions, including earthquakes and climate change. Sustainability practices are realized through the utilization of renewable materials, passive energy efficiency via natural ventilation, and a symbiotic relationship with marine ecosystems. Regional variations are found in specific material choices and forms of adaptation, influenced by local resource availability, geographical characteristics, and socio-cultural factors. This study highlights the indigenous knowledge of the Bajo people as a valuable source of inspiration for contemporary adaptive and sustainable architecture in facing global climate change challenges.

Keywords: *Bajo Architecture; Structural Adaptation; Sustainability; Meta-Analysis; Traditional Maritime Construction; Indigenous Knowledge; Climate Resilience.*

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I. INTRODUCTION

➢ *Background*

The Bajo people, often dubbed "sea nomads" or "sea gypsies," are a maritime ethnic group who traditionally live a nomadic life on boats or inhabit floating settlements in coastal areas and archipelagos of Southeast Asia, including various parts of Indonesia. Their life, which is heavily dependent on the sea, has shaped their culture, livelihoods, and, naturally, their unique architecture. The maritime environment they inhabit, characterized by extreme sea level fluctuations, waves, strong currents, high winds, and high humidity, presents significant construction challenges [1,2]. However, through indigenous knowledge passed down through generations and deep observation of nature, the Bajo people have developed highly adaptive and sustainable forms of architecture, capable of withstanding harsh environments while maintaining ecological balance [3,4]. The formatter will need to create these components, incorporating the applicable criteria that follow.

The traditional architecture of the Bajo people, predominantly stilt houses built over water, is more than just shelter. It is a manifestation of the symbiotic relationship between humans and the sea, a system integrated with aquatic ecosystems and natural cycles. The building structures, material selection, orientation, and even the internal spatial arrangements are all designed to respond to environmental conditions while reflecting the cultural and social values of their community [2,4] In the context of increasingly evident global climate change and threats to coastal ecosystems, a deep understanding of adaptive and sustainable architectural practices, such as those demonstrated by the Bajo people, becomes ever more relevant and urgent.

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- *Problem Statement*

Although numerous case studies have examined Bajo architecture in various locations across Indonesia, most of these studies tend to be localized and descriptive. This leads to fragmentation of knowledge and makes it difficult to identify common patterns of structural adaptation, construction innovations, and sustainability principles that apply broadly across Bajo communities in Indonesia. This gap hinders the comprehensive synthesis of knowledge, which is critically needed to formulate broader implications for contemporary architecture and sustainable coastal settlement planning. Furthermore, the potential of Bajo architecture as a model for climate resilience and sustainability is often not fully explored from a meta-analytical perspective.

- *Research Objectives*

This study aims to conduct a meta-analysis of existing scientific literature on Bajo architecture in Indonesia, with the following specific objectives:

- To identify common patterns of structural adaptation in Bajo architecture to maritime environmental challenges (tides, waves, strong currents, high winds).
- To analyze the traditional construction innovations applied in the building of Bajo houses.
- To identify and examine the sustainability principles integrated into Bajo architectural practices.
- To explore regional variations in Bajo architecture in Indonesia and the socio-cultural and geographical factors influencing them.

- *Research Questions*

Based on the above objectives, the main research questions to be answered are:

- How does Bajo architecture structurally adapt to the dynamic maritime environment in various regions of Indonesia?
- What traditional maritime construction innovations are identified in the architecture of the Bajo people?
- What sustainability principles underpin and are embodied in Bajo architecture in Indonesia?
- What socio-cultural, geographical, and environmental factors contribute to variations in Bajo architecture across different communities in Indonesia?

- *Significance*

The results of this meta-analysis are expected to make significant contributions in several aspects:

- *Academic:*

Provide a comprehensive synthesis of knowledge about Bajo architecture, filling gaps in the literature, and enriching theories of vernacular architecture, environmental adaptation, and sustainability.

- *Practical:*

Offer insights and inspiring design models for architects, urban planners, and policymakers in developing adaptive and sustainable architectural solutions for coastal settlements in the era of climate change.

- *Socio-Cultural:*

Document and promote the indigenous knowledge of the Bajo people as a form of intangible cultural heritage that is highly relevant and valuable in the context of sustainable development.

II. LITERATURE REVIEW

- *Vernacular Architecture and Environmental Adaptation*

Vernacular architecture refers to traditional forms of architecture that evolve from local needs, material availability, and responses to local climate and culture, without the intervention of professional designers [5]. It is a product of the collective wisdom of a community, passed down through generations, reflecting a deep understanding of the environment and how to live harmoniously with it. In the context of environmental adaptation, vernacular architecture often serves as the most efficient and sustainable model, having undergone centuries of testing and evolution [6].

For maritime communities like the Bajo people, environmental adaptation is key to survival. The aquatic environment presents unique challenges: extreme sea level fluctuations, strong waves and currents, high winds, high humidity, and threats of natural disasters such as tsunamis [7]. The vernacular architecture of the Bajo people, characterized by stilt houses or floating structures, is a direct response to these challenges. This adaptation is not only structural but also involves site selection, building orientation, and spatial arrangement that maximize the utilization of natural resources (e.g., wind for ventilation) while mitigating [1,8,9].

- *Principles of Sustainability in the Context of Traditional Architecture*

The concept of sustainability in traditional architecture predates modern definitions of "green architecture" or "sustainable buildings." It is inherently integrated into vernacular construction practices through several key principles:

- *Utilization of Local and Renewable Materials:*

Building materials are sourced from the surrounding environment, reducing the carbon footprint from transportation and industrial material production. These materials are generally renewable and easily reintegrated into nature [10].

- *Passive Energy Efficiency:*

Building designs optimize natural lighting, cross-ventilation, and thermal insulation without relying on energy-intensive mechanical technologies. This is highly relevant for Indonesia's tropical climate [10,11].

- *Recycling and Waste Minimization:*

Materials can often be reused or recycled, and construction waste is minimal due to the use of natural materials.

- *Resilience and Durability:*

Buildings are designed to be durable and easily repaired with local resources, as well as capable of withstanding extreme environmental conditions or natural disasters [11,13].

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- *Environmental Wisdom:*

Architecture reflects a deep understanding of local ecosystems and efforts to maintain ecological balance [3]. For example, construction that does not damage coral reefs or mangrove forests.

In Bajo architecture, these principles are tangibly realized. The use of wood from mangrove forests for stilts, sago palm for roofs, and bamboo for walls and floors are classic examples of utilizing local and renewable materials. The high stilt house structures and appropriate roof designs are passive energy efficiency strategies for air circulation and protection from heat and heavy rain [11].

➢ *Previous Studies on Bajo Architecture*

Research on Bajo architecture has been conducted in various locations across Indonesia, such as Torosiaje (Gorontalo), Parigi Moutong (Central Sulawesi), Bone (South Sulawesi), Wakatobi (Southeast Sulawesi), and others. These studies are generally descriptive and exploratory, documenting the physical characteristics, materials, and construction techniques of Bajo houses.

For instance, Nurjannah (2024) and Karim (2024) highlight the adaptation and indigenous knowledge in Bajo house architecture in Torosiaje Laut, Gorontalo, including variations in house forms and responses to the aquatic environment [1,4]. Rifai (2010) examines the development of Bajo house structures and construction in Parigi Moutong, showing the evolution from using local materials to adapting modern technology [11]. Rubama, at al (2024) discuss the social and ecological adaptation of Bajo communities, including how their settlements support fish habitats and indigenous knowledge in disaster mitigation (18).

Despite these studies providing valuable insights into specific aspects of Bajo architecture, several gaps exist:

✓ *Data Fragmentation:*

Data on materials, techniques, and adaptations are scattered across various case studies, making it difficult to identify common patterns and systematic cross-regional comparisons.

✓ *Lack of In-depth Comparative Analysis:*

Most studies focus on a single location or a single aspect, without in-depth cross-regional comparisons to identify factors driving variations.

✓ *Limited Focus on Holistic Sustainability:*

Although environmental adaptation aspects are often mentioned, a more holistic framework of sustainability (encompassing ecological, social, economic dimensions) is rarely the primary focus. This meta-analysis aims to bridge these gaps by synthesizing findings from various studies, identifying broader patterns, and formulating a more comprehensive understanding of the structural adaptation and sustainability of Bajo architecture throughout Indonesia.

III. METHODOLOGY

➢ *Research Design*

This study employs a meta-analytical approach. Meta-analysis is a scientific method that systematically synthesizes results from various independent studies on the same topic to identify patterns, relationships, or differences that may not be apparent from individual studies (Glass, 1976). This approach allows researchers to integrate qualitative and quantitative findings from diverse literature, providing a more comprehensive understanding and stronger generalizations about the structural adaptation and sustainability of Bajo architecture in Indonesia.

➢ *Literature Search Strategy*

A systematic and comprehensive literature search was conducted on leading scientific databases to ensure broad coverage and relevance of studies. The databases used include:

- Scopus
- Web of Science
- Google Scholar
- Neliti.com (Indonesian journal portal)
- Indonesian University Repositories (e.g., UGM, UI, ITB, UNHAS, UHO, UNISAN)

Keywords used, in both Indonesian and English, included combinations of:

- "Arsitektur Suku Bajo" OR "Rumah Bajo" OR "Hunian Bajo" OR "Permukiman Bajo"
- "Bajo architecture" OR "Bajau house" OR "Bajau settlement"
- "Adaptasi struktural" OR "Structural adaptation"
- "Keberlanjutan" OR "Sustainability"
- "Inovasi konstruksi" OR "Construction innovation"
- "Maritim tradisional" OR "Traditional maritime"
- "Material lokal" OR "Local materials"
- "Resiliensi iklim" OR "Climate resilience" The search period was limited from 2000 to October 2025 to ensure the relevance and currency of the data.

➢ *Inclusion and Exclusion Criteria*

To ensure the relevance and quality of the studies, strict inclusion and exclusion criteria were applied during the screening and selection stages:

- *Inclusion Criteria:*

✓ Studies focusing on the architecture of the Bajo people (or variations such as Bajau/Sama) in Indonesia.
✓ Studies presenting empirical data or in-depth analysis of the structural adaptation of Bajo architecture to the maritime environment (e.g., to tides, waves, currents, wind).
✓ Studies discussing the types of construction materials used and their innovations in Bajo architecture.
✓ Studies identifying or analyzing sustainability principles (e.g., use of local/renewable materials, passive energy efficiency, recycling, climate resilience, environmental management) in Bajo architecture.

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- ✓ Studies published in peer-reviewed scientific journals, conference proceedings, master's theses, or doctoral dissertations.
- ✓ Studies available in full-text format.

- *Exclusion Criteria:*

- ✓ Studies discussing only general cultural aspects of the Bajo people without direct relevance to their architecture, structure, or sustainability.
- ✓ Studies on Bajo people outside Indonesia (e.g., Malaysia, Philippines).
- ✓ Studies consisting of news articles, blogs, opinions, or non-academic content.
- ✓ Studies with unclear methodologies, unverifiable data, or low quality.
- ✓ Studies not accessible in full-text format.

➢ *Study Selection Process*

The study selection process was conducted in systematic stages:

- *Initial Identification:*

Search results from all databases were combined, and duplicates were removed.

- *Title and Abstract Screening:*

Titles and abstracts of the remaining studies were screened based on initial inclusion and exclusion criteria. Clearly irrelevant studies were immediately excluded.

- *Full-Text Evaluation:*

Studies that passed the initial screening were downloaded and read in full-text. Re-assessment was performed based on more detailed inclusion and exclusion criteria. Studies that did not meet the criteria were excluded, with reasons noted.

- *Final List of Studies:*

The result was a final list of relevant and high-quality studies to be included in this meta-analysis. This process ensured that only the most relevant and credible literature was analyzed.

➢ *Study Selection Process*

For each selected study, relevant data were systematically extracted using a pre-developed protocol. This data extraction protocol included the following categories of information:

- *Bibliographic Information:*

Author(s), publication year, title, type of publication (journal, thesis, etc.).

- *Geographical Location of Study:*

Name of village, district, and province in Indonesia where the research was conducted (e.g., Torosiaje Laut, Gorontalo; Parigi Moutong, Central Sulawesi).

- *Construction Material Types:*

Main materials used for various building components (foundations, stilts, structure, walls, floors, roofs). Examples: mangrove wood, posi-posi wood, ironwood, bamboo, sago palm, nipa leaves, zinc, concrete.

- *Construction Techniques:*

Methods of construction and joining structural elements (e.g., stilt system, floating system, interlocking joinery, pile foundations, precast concrete piles).

- *Adaptive Solutions to Maritime Environment:*

Detailed descriptions of how architectural design addresses marine environmental challenges (e.g., stilt height, house orientation, roof design, under-house air circulation, resistance to waves/currents/wind).

- *Principle of Sustainability Identified:*

Evidence of sustainability practices (e.g., use of local/renewable materials, recycling, passive energy efficiency, climate resilience, environmental management, indigenous knowledge in resource management).

- *Socio-Cultural Factors:*

Influence of culture, beliefs, livelihoods, lifestyle, social hierarchy, and interactions with other ethnic groups on architecture and settlements.

- *Construction Innovations:*

Changes, adaptations, or developments in techniques and materials observed over time or in response to new challenges. The extracted data were presented in tabular or matrix format to facilitate comparative analysis.

➢ *Data Analysis*

The extracted data were analyzed using a combination of qualitative methods:

- *Thematic Analysis:*

Qualitative data were thematically analyzed to identify recurring patterns, key themes, and central concepts emerging from the literature. This helped in grouping structural adaptations, innovations, and sustainability practices.

- *Comparative Analysis:*

A systematic comparison was conducted among studies from different geographical locations to identify similarities and differences in Bajo architecture. This helped explain regional variations and the factors influencing them (e.g., material availability, wave intensity, local culture).

- *Narrative Synthesis:*

Findings from the thematic and comparative analyses were synthesized into a coherent narrative, integrating various aspects of Bajo architecture and linking them to theories of environmental adaptation and sustainability. This process formed the basis for the Results and Discussion sections of the journal manuscript. This analysis allowed for drawing strong conclusions regarding Bajo architecture as a model of adaptive and sustainable traditional maritime construction innovation.

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IV. RESULTS

A meta-analysis of the 24 selected studies revealed consistent patterns and significant variations in the structural adaptation and sustainability practices of Bajo architecture in Indonesia. These findings are categorized into general characteristics, structural innovations, local materials and resilience, sustainability principles, and regional variations.

➢ *General Characteristics of Bajo Architecture*

Fundamentally, Bajo architecture in Indonesia is characterized by stilt houses built over water, either on the coast, extending into the sea, or entirely floating or on coral clusters. Settlement patterns tend to be linear, following coastlines or the routes of wooden bridge circulation, and are located close to their livelihoods [11,12]. These houses are generally simple in size but highly functional, supporting a maritime way of life.

An integral part of Bajo settlements is the area for mooring boats (sampan or lepa-lepa), often located beside or beneath the house, emphasizing the interdependence between dwelling and means of transport/livelihood [11]. This indicates that Bajo architecture is not just about physical structures but about an integrated system of life.

➢ *Maritime Structural Innovations*

Bajo architecture has developed several structural innovations to address the challenges of the marine environment:

- *Adaptive Pile Foundation System*

The most prominent innovation is the pile foundation system, with stilts deeply embedded into the seabed. These stilts, which are often made of mangrove wood, posi-posi wood, or ironwood, are planted to a depth of 1-3 meters into sandy soil or coral. The height of the stilts above water varies, typically between 3-4 meters, adjusted to cope with tidal fluctuations and keep the house safe from inundation [4,11]. In Parigi Moutong, posi-posi wooden stilts are used to support the roof trusses and floor [14].

A crucial characteristic of these foundations is their elasticity. Deeply embedded wooden stilts, which are not overly rigid, allow the house to sway slightly with the water's movement and absorb wave energy. This also provides resilience against earthquakes, where elastic wooden structures are more resistant to tremors than rigid buildings [11].

- *Interlocking Joinery System and Flexibility*

In many cases, Bajo house structures use an interlocking joinery system instead of nails, especially in early construction. Rattan ropes or similar materials are used to bind wooden parts together [15]. This interlocking joinery provides the structural flexibility needed to withstand pressure from waves and wind without permanently damaging the building's integrity. It allows the structure to adapt to small deformations without catastrophic failure.

- *Roof Design and Functional Orientation*

Roof designs are generally gable or hipped, utilizing sago palm, nipa leaves, or zinc materials. In Torosiaje, high roofs with a 45-degree pitch are found to be effective in protecting against heavy rain and reducing heat absorption, while air circulation from the space beneath the house functions as a natural "aquarium," helping to cool the interior [11].

House orientation is also highly functional, utilizing sufficient openings for natural lighting and cross-ventilation, maximizing sea views, and capturing breezes. This helps reduce humidity and heat, creating a comfortable interior environment [10].

- *Local Materials and Resilience*

The use of local and renewable materials is a hallmark of Bajo architecture, simultaneously serving as a pillar of sustainability and resilience:

✓ *Wood:*

Various types of wood are extensively used.

▪ *Mangrove Wood:*

Used for stilts due to its availability and resistance to aquatic environments [11].

▪ *Posi-posi Wood (Mangrove species):*

Known for its resistance to seawater and abundance in Central Sulawesi's coast, used for house stilts [11].

▪ *Ironwood (Kayu Ulin):*

Used in Kalimantan (Rampa Kampis Village) for columns and beams due to its exceptional resistance to sun exposure and prolonged immersion in seawater [14].

▪ *Seraya, Resak, Meranti, Bemanggul, Mentano Woods:*

Used by the Indigenous people (Orang Laut) in Tajur Biru for piles, chosen for their water resistance [15].

✓ *Bamboo***:**

Used for floors and walls due to its flexibility and availability [16].

✓ *Sago Palm and Nipa Leaves:*

Used as roofing materials due to their good thermal insulation properties and availability [10].

✓ *Coral Reefs and Shells:*

Some studies mention the unique tradition of using natural marine materials like coral reefs and shells in traditional house construction [15].

This combination of materials not only reduces costs and environmental impact but also allows for easy repair and replacement using local resources when damage occurs 16]. This forms the foundation of resilience, where communities can independently maintain their dwellings.

➢ *Integrated Sustainability Principles*

Bajo architecture inherently integrates sustainability principles:

- *Utilization of Local & Renewable Resources:*

As explained above, sourcing materials from the surrounding environment is a core practice [10].

- *Passive Energy Efficiency:*

Stilt house designs with ample openings, appropriate orientation, and suitable roof designs maximize natural ventilation and lighting, reducing the need for artificial cooling or illumination [11,18].

- *Climate & Disaster Resilience:*

Bajo architecture demonstrates high adaptability to climate change and disaster mitigation. Elastic stilt house designs and seawater-resistant materials reduce vulnerability to storms, sea-level rise, and earthquakes [11,13].

- *Environmental Wisdom & Symbiosis:*

Bajo settlements are often built close to coral reefs and mangrove forests rich in marine resources, demonstrating an understanding of ecosystems. Furthermore, their settlement architecture can serve as a supporter of marine fish habitats, creating a mutualistic symbiotic system [3,11].

- *Recycling*:

Although not explicitly stated in all studies, the reuse of materials and maximum utilization of local resources indicate recycling practices and waste minimization.

➢ *Regional Variations and Driving Factors*

While general patterns exist, the meta-analysis also identified significant regional variations in Bajo architecture, influenced by the following factors:

- *Availability of Local Natural Resources:*

The types of wood used highly depend on the flora available around the settlement location. For example, the dominance of posi-posi wood in Parigi Moutong versus ironwood in Kalimantan [11,14].

- *Specific Geographical & Environmental Characteristics:*

Marine conditions (wave intensity, currents, water depth) influence stilt height, structural strength, and house orientation. For instance, houses in Torosiaje Laut are designed to face waves and strong winds in Tomini Bay [4,11].

➢ *Socio-Cultural Factors:*

- *Shifting Lifestyles:*

Some Bajo communities have experienced a shift from a nomadic maritime culture to semi-land-based living, which affects settlement forms and materials used [6].

- *Interaction with Other Ethnic Groups:*

In some locations in Gorontalo, Bajo architecture shows a tendency to adopt traditional Gorontalo house forms, indicating cultural assimilation or social influence [17].

- *Social Hierarchy and Cultural Values:*

Spatial patterns within houses, such as the sacred *watangpola* section, reflect the cultural values and social hierarchy of the Bajo community [1].

➢ *Influence of Modernization and Technology:*

The emergence of modern materials like zinc for roofs or precast concrete piles indicates adaptation to the availability of industrial materials, although often still combined with traditional techniques and materials [14]. This can also be a form of adaptation to increasingly extreme environmental conditions, as modern materials are sometimes considered stronger [17].

Overall, these variations demonstrate the dynamism of Bajo architecture as a living system, continuously adapting to environmental and social changes while retaining the core of their indigenous knowledge.

V. DISCUSSION

The findings from this meta-analysis comprehensively support the idea that Bajo architecture in Indonesia is an outstanding model of structural adaptation and sustainability. These research results have significant theoretical and practical implications.

➢ *Theoretical Implications*

The primary contribution of this research is the synthesis of previously fragmented knowledge, which strengthens and expands theories of vernacular architecture and environmental adaptation.

- *Validation of Vernacular Architecture as the Best Environmental Response:*

This study validates that Bajo architecture is not merely a cultural product but a highly effective and time-tested response to extreme maritime environmental conditions. Structural innovations such as elastic pile foundations and interlocking joinery exemplify how empirical knowledge can yield robust engineering solutions without formal modern calculations [14,11]. This reaffirms the view that vernacular architecture is often the most sustainable and efficient form of adaptation due to its long evolutionary process.

- *Holistic Sustainability in Traditional Contexts:*

The meta-analysis shows that sustainability in Bajo architecture is not a separate concept but is holistically integrated into every aspect: from site selection (near resources), materials (local, renewable), construction (minimal waste, easy repair), to function (supporting livelihoods, disaster resilience). This challenges modern perceptions that often compartmentalize sustainability as an add-on or 'green' feature, instead emphasizing that sustainability is an inherent way of life [3,10].

- *Dynamics of Cultural-Environmental Adaptation:*

Regional variations indicate that Bajo architectural adaptation is not static. It is a dynamic process influenced by the interplay of local resource availability, specific geographical characteristics, and socio-cultural factors such as shifting lifestyles and inter-ethnic interactions. This enriches the understanding of how culture and environment mutually shape each other in the context of architecture, and how indigenous knowledge can accommodate change [17].

➢ *Practical Implications*

The research findings are highly relevant for architectural practice, urban planning, and sustainable development policies, particularly in coastal areas.

- *Climate-Adaptive Design Model:*
  Bajo architecture offers a blueprint for designs proven resilient to the impacts of climate change, such as sea-level rise, storms, and earthquakes. Principles like elastic foundations, lightweight yet strong materials, and designs for natural air circulation can be adapted into modern designs for more resilient and sustainable coastal settlements [11,13].

- *Sustainable Local Material Utilization:*
  The emphasis on local and renewable materials in Bajo architecture underscores the importance ofv a circular economy and reducing carbon footprint in construction. This can encourage the development of sustainable local material industries and reduce reliance on energy-intensive imported materials.

- *Integration of Indigenous Knowledge in Coastal Planning:*
  Governments and planners should integrate the indigenous knowledge and adaptive practices of the Bajo people into coastal spatial planning policies. This is not just about preserving cultural heritage but also about utilizing time-tested solutions for more robust and sustainable development. Settlement models that support ecosystems (e.g., fish habitats) can be considered in ecotourism or sustainable settlement development [3].

- *Education and Knowledge Transfer:*
  Knowledge about construction innovations and sustainability principles from Bajo architecture should be integrated into architectural and civil engineering curricula, as well as community training programs to promote sustainable building practices.

➢ *Limitations of the Study*

Although this meta-analysis has synthesized a substantial body of literature, several limitations exist:

- *Data Heterogeneity:*
  Primary studies vary in methodology, depth of analysis, and location, which can affect the ability to draw absolute generalizations. Some studies lack detailed quantitative data on structural performance.

- *Publication Bias:*
  Meta-analysis can only include published or available studies, potentially overlooking unpublished or difficult-to-access research.

- *Limited Information on New Innovations:*
  Existing literature may not fully capture the latest innovations or adaptations currently underway in Bajo communities in response to contemporary challenges.

➢ *Future Research Directions*

Based on these limitations, future research can focus on:

- *Quantitative Empirical Studies:*
  Conducting more quantitative empirical studies on the structural performance of Bajo architecture using CFD (Computational Fluid Dynamics) simulations or material testing to validate resilience and efficiency.

- *Longitudinal Analysis:*
  Conducting longitudinal studies to track the evolution of Bajo architecture and how it continues to adapt to climate change and modernization over time.

- *Community Participation:*
  Directly involving Bajo communities in the research process to gather firsthand knowledge and experiences about their construction and sustainability practices.

- *Cross-Cultural Comparison:*
  Expanding comparisons to vernacular maritime architecture of other ethnic groups in Southeast Asia to identify universal principles of environmental adaptation.

VI. CONCLUSION

This meta-analysis has successfully synthesized diverse scientific literature to present a comprehensive overview of the structural adaptation and sustainability of Bajo architecture in Indonesia. The research findings clearly demonstrate that Bajo architecture is an outstanding example of traditional maritime construction innovation that is highly adaptive and resilient to ynamic aquatic environments.

It was found that stilt houses built with local and renewable materials are central to Bajo architecture. Structural innovations such as deep and elastic pile foundations, flexible interlocking joinery, and passively efficient roof designs and orientations allow Bajo dwellings to withstand tides, waves, strong winds, and even demonstrate resilience against earthquakes and climate change. Sustainability principles are inherently integrated through the utilization of local resources, passive energy efficiency, and a symbiotic relationship with marine ecosystems. Although there are regional variations driven by material availability, geographical characteristics, and socio-cultural factors, the core indigenous wisdom of living harmoniously with the sea remains consistent.

The contribution of this research is to fill a literature gap by providing a consolidated synthesis, enriching vernacular architecture theory, and offering practical insights for contemporary adaptive and sustainable architectural design amidst global climate challenges. Bajo architecture is living proof that the most robust and harmonious solutions with nature often stem from traditional knowledge and practices. Therefore, the preservation, understanding, and learning from this indigenous wisdom are crucial for the future of sustainable architecture.

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