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The Resilience of Traditional Indonesian Architecture: A Review of Existing Research

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Abstract

The rapid rise of modern lifestyles and technologies, along with disturbances to natural imbalances, has threatened the resilience of traditional architecture worldwide, including Indonesia. While some communities embrace modern structures as symbols of contemporary life, others adapt traditional buildings to changing needs while maintaining cultural identity. This study examines the resilience of Indonesian traditional architecture through a systematic review of 40 cases taken from existing research articles. It applies a resilience framework for the data analysis to reveal the extent to which the architecture responds to current changes and imbalances. Findings show two tendencies: modernisation drives changes in materials, layouts, and functions, while enduring connections to climate, spatial logic, and cultural principles. Adaptations range from substantial modifications that retain structural and functional integrity to superficial applications of traditional ornamentation on modernised buildings. Although a few cases fail to adapt, most demonstrate adaptive resilience, maintaining both function and cultural meaning.

INTRODUCTION

Traditional architecture is widely understood as a system that has undergone a long period of transformation to fit the constraints of the place where the building is situated, as well as the needs and wants of the inhabitants (Oliver, 2006; Petzet & Ziesemer, 2002). The system that encompasses the site, structure, and occupants has reached its balance state, resulting in a stable architecture that is recorded in history and might still be observed today. The long tradition of maintaining and observing social and cultural values, combined with a tacit knowledge of solving construction problems due to climate and natural disasters, has shaped and sustained the architecture's design (Oliver, 2006). However, current changes in many aspects of life and disturbances from natural imbalances have threatened the existence of this architecture. Some of them may survive the obtrusive forces, some may be transformed and still functioning, and the rest perish.

The ability of traditional architecture to iteratively engage with change and disturbance, as described above, represents the present-day idea of resilience. Resilience, as stated by The Rockefeller Foundation, is the capacity of individuals, communities, and systems to respond and adapt in the face of disturbance or change, and even transform when the conditions require it (Laboy & Fannon, 2016). The traditional architecture, as indicated above, has endured various physical and non-physical disturbances and changes over an extended period, proving its ability to withstand them. This architectural quality is essential for maintaining architectural existence, particularly in the face of rapid societal, economic, technological, and environmental changes. Maintaining ideas and forms of traditional architecture is not only important for history, identity, and social and cultural continuity, but also advantageous for contemporary architectural design development (Aboulnaga & Mostafa, 2019; Oliver, 2006; Trombadore & Visone, 2019).

Traditional architecture in Indonesia is an excellent representation of architectural diversity that stems from a wide variety of ethnicities, socio-cultural values, environmental and geographical conditions (Schefold et al., 2004). The way the community sees the world and perceives the environment has shaped social and cultural norms and

architecture. All individuals in the community shared the same values, and this communal perspective is reflected in their dwellings. Over decades, however, changes in their architecture have been happening (Schefold et al., 2004), and continue up to the present. The way people live and perceive the world has changed, affecting how they treat their traditional dwellings. Parts of the building have been transformed into a modern building style, resulting in a mix of architectural styles. In a worst-case scenario, the traditional building was abolished and replaced with a new, modern structure that lacks traditional expression and construction methods. For some people, living in a modern house is a representation of a contemporary lifestyle. In other cases, traditional dwellings only experienced a few or moderate modifications and transformations. For the occupants, this transformation is a way to retain the cultural identity and memory of the past while adapting to a new lifestyle.

Aside from the non-physical external pressures mentioned above, traditional dwellings in some parts of Indonesia also experienced the impact of natural disasters, ranging from earthquakes, tsunamis, landslides, and floods (Muqoffa et al., 2025; Nasution et al., 2020; Rajendra, 2021; Rini & Idham, 2021). These external disturbances could have a detrimental effect on the dwellings, so in the worst case, the building needs to be demolished. The structure was no longer safe, and the occupants could not live in the building. Some buildings can survive and require minor to moderate repairs. These conditions show how traditional dwellings were designed and constructed with an awareness of and attention to the positive and negative impacts of the place.

Many studies have been conducted in the last decade to describe and explain the architectural phenomenon of traditional Indonesian architecture, focusing on the impact of various external forces on the buildings. The first embraces the influence of natural disturbance (Muqoffa et al., 2025; Nasution et al., 2020; Rajendra, 2021; Rini & Idham, 2021). The second investigates the effects of socio-cultural changes (Fadhilah et al., 2024; Nasution et al., 2022; Yosantia et al., 2023; Yusran & Dirgantara, 2021). The last category of study concerns other forces, such as the economy (Matondang & Sani, 2021), tourism (Budihardjo, 2019; Ermayanti et al., 2023), and material and technology (Dafrina et al., 2022; Muqoffa et al., 2025). The majority of the studies do not explicitly focus on the resilience quality of traditional dwellings. They did explain how the dwelling changed and transformed due to external influences, but they do not refer to any concepts of resilience. Few studies have examined the resilience of buildings, focusing instead on particular traditional dwellings (Lindarto & Defriza Harisdani, 2024; Rahmi, 2017; Sasongko et al., 2025).

The present study aims to gather the published research on traditional Indonesian architecture for the last decade and examine it within the resilient architecture framework. The objective is to analyse resilient architectural concepts in traditional architecture across Indonesia and to identify their current patterns. The study contributes to extending the knowledge about the resilient architecture of traditional dwellings in Indonesia, which, as previously mentioned, is very limited and partially explored based on specific locations or cases. In a broader context, as stated by previous studies (Lindarto & Defriza Harisdani, 2024; Oliver, 2006), maintaining resilient ideas of traditional Indonesian architecture is intended to evoke awareness of cultural identity, continuity, and sustainable design.

LITERATURE REVIEW

Concept of Resilience Architecture

The concept of resilience in architecture or the built environment in general was influenced, in part, by Holling's (1973) definition of resilience in ecology. Resilience here is defined as the ability of a system to absorb change and disturbance while persisting, maintaining the same relationships between state variables. Another definition that arose from the engineering discipline also contributes to the concept of resilience in architecture. From this discipline standpoint, resilience is defined as a system's capacity to absorb and recover from a hazardous disturbance or change (Timmerman, 1981). Laboy and Fannon (2016) describe the first concept as ecological resilience and the second concept as engineering resilience. The first focuses on persistence, redundancy, and resourcefulness, while the second focuses on constancy, robustness, and rapidity. In both cases, the context is fixed, and the system moves. In the first case, the system engages with multiple equilibrium states, whereas in the second, it interacts with a stable equilibrium.

Unlike ecology and engineering, architecture is closely tied to its context, which is influenced by a range of multifaceted factors. As a result, the concept cannot be determined by only one or two definitions. This condition is best described as adaptive resilience by Laboy and Fannon (2016). This concept focuses on transformability, adaptability, and recovery. Here, the system encounters dynamic stability and multiple equilibrium scales. To accommodate these complex factors affecting architecture, Genadt (2019) proposed a definition of resilient architecture as a building's capacity to support a village or city in maintaining system balance during periods of change or disruption. Architecture is a system that comprises several subsystems, such as spatial, formal, structural, and service systems. In the face of disturbance, the external forces act on the system, and the subsystems respond accordingly. The subsystem may give the same response, or the subsystem may react separately. The building,

therefore, may have one or more capabilities to balance the overall system and ensure its function. For architecture, the disturbance could occur over a short to an extended period (Laboy & Fannon, 2016)

Framework of Resilience Architecture

Amico and Currà (2014) have summarized the resilience framework to provide a more comprehensive assessment of buildings, especially within the multidisciplinary context. Some aspects of the framework are also adopted separately in the study of architecture (Laboy & Fannon, 2016; Vishwakarma & Rani, 2023; Yuniartanti et al., 2024). There are three main aspects considered in this framework, namely resilience capacity, resilience properties, and resilience domain/dimensions. Resilience capacity refers to the ability of the built environment to manage disturbances. Resilience properties are characteristics or strategies of built environments that enable them to adapt to and manage disturbances. The resilience domain refers to the areas where the built environment may experience impacts of disturbances. Conditions of the domain will contribute to the state of the properties. Each aspect of the framework includes several components, which are highlighted in Table 1 below.

Table 1. Aspects And Components of The Resilience Framework

Aspect	Components	Definitions	Sources
Capacity	Absorptive	The degree to which a system can absorb the impacts of system perturbations and minimize consequences with little effort	Amico and Currà (2014)
	Adaptive	The ability of a system to adjust to undesirable situations by undergoing some changes	
	Restorative	The ability of a system to return to normal or improved operations and system reliability rapidly	
Principles / Property	Rapidity	The speed at which the system must either limit or recover from a disturbance	Amico and Currà (2014); Bruneau et al. (2003)
	Robustness	The strength of systems to resist disturbance	
	Redundancy	The capacity that enables the system to continue to function during a period of disturbance	
	Resourcefulness	Organizational capacity to detect and respond to disturbance	
Domain / Dimension	Technical	Physical attributes, including the built environment	Amico and Currà (2014); Bruneau et al. (2003); Laboy and Fannon (2016)
	Organizational	Institutions that produce regulations, policies, and plans	
	Social	Vulnerabilities and the adaptive strengths of individuals and the community	
	Economic	The capacity of local or regional economies to respond to change	

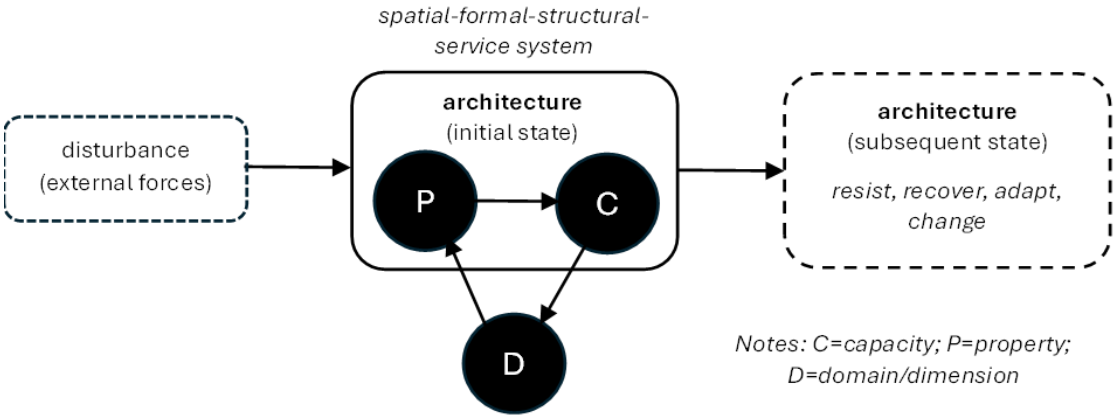


Fig. 1. Relationship Between Three Aspects of Resilience in Architecture
(Source: Author)

When a disturbance acts on architecture, its subsystem will respond to it. The system utilizes its property to perform an action (i.e., capacity). Conditions of the area where the disturbance affects (i.e., domain) will define the state of the property. All these conditions determine the subsequent state of architecture. It may resist, recover, adapt or change (Fig. 1). Since architecture may experience many kinds and states of disturbances, such as natural disasters, social and cultural change, and technological shifts, the response may take different forms. Laboy and Fannon (2016) identified three types of responses. The first is resistance, that is, when the form returns to its initial state. The second is adaptation that occurs when the form transforms partly into a new state while retaining some of its other subsystems as its initial state. The last is change, that is, when the form changes completely into a different state. In the case of architecture, the response could take one or more types of responses. Elaboration of the three types of responses by Laboy and Fannon (2016) is given in Fig. 2.

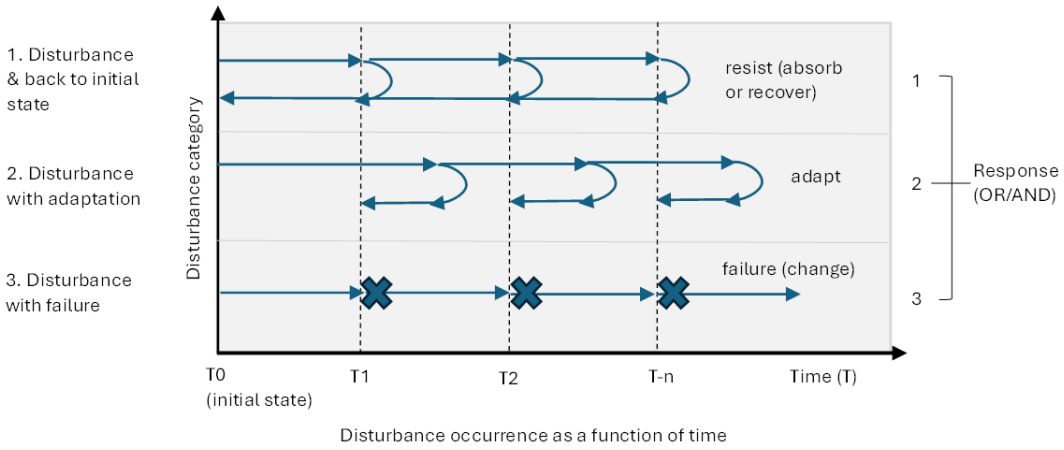


Fig. 2. The Type of Response of Architecture in the Face of Disturbance (Source: Adapted from Laboy and Fannon (2016))

METHODS

Research Method and Data Collection

This study examines the resilience of traditional architecture across Indonesia through a structured literature review. It is a qualitative synthesis of secondary data derived from published case studies. Peer-reviewed journal articles published between 2015 and 2025 and indexed in Scopus, Google Scholar, and SINTA form the primary data source. The search strategy employed keywords such as "traditional architecture", "resilient architecture", "vernacular housing", and "vernacular transformation", combined with geographical terms (e.g., Bali, Central Java, North Sumatra) and typological terms (e.g., Joglo, Gadang, Tongkonan). The review focuses on articles that discuss architectural resilience, including aspects of climate adaptability, structural performance, and socio-cultural continuity.

The final selection comprises 37 articles, which collectively present 40 distinct case studies, as some sources analyze multiple architectural types and locations (Basri et al., 2025; Rajendra, 2021). These cases offer broad geographical representation and were classified at the provincial level before being aggregated into six island groups for comparative analysis (Bali and Nusa Tenggara, Java, Kalimantan, Maluku and Papua, Sulawesi, and Sumatra). This grouping strategy helps minimize regional bias while accommodating similarities in geographical and environmental contexts. While the primary focus is on residential dwellings ($n = 37$), the study also includes three cases of public or utilitarian structures (palaces, markets, and rice barns) to ensure a broader perspective on resilience. Fig. 3 maps the geographical distribution of these cases, and **Error! Reference source not found.** summarizes the the existing research articles.

Data Analysis and Discussion

Furthermore, this research applies the resilience framework established earlier in this study as the analytical lens for examining the selected literature, structured around three components: domains, principles, and capacities (Table 1). The Results and Discussion section presents the analysis in the order of domains (what drives change), principles (how communities respond), and capacities (the outcomes), allowing the discussion to move from specific

observations to broader implications. This analytical sequence was adopted to support cross-case comparison across regions and to synthesize patterns of architectural resilience strategy.

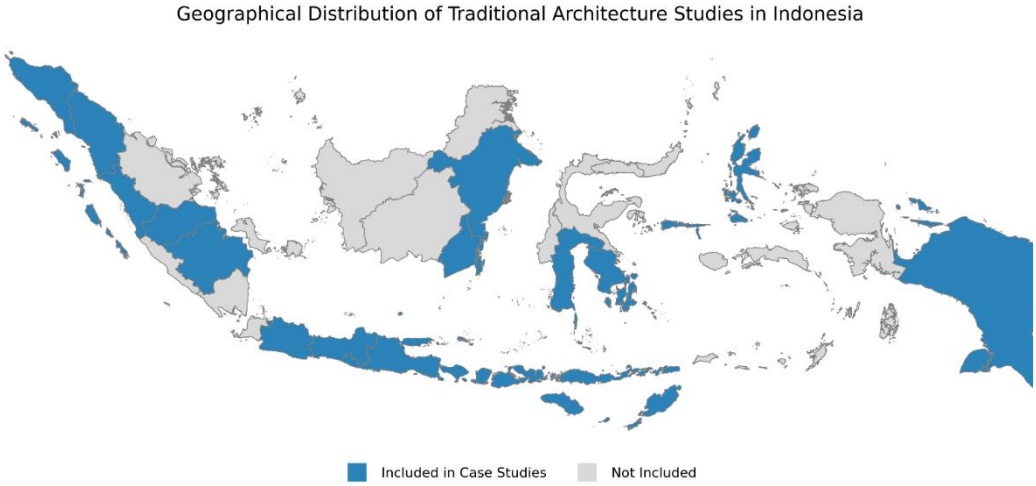


Fig. 3. Distribution of the Article's Case Study
(Source: Author)

Table 2. Overview of Case Studies Included in the Analysis

Regions	*n*	Provinces	Authors (Year)	Case Studies
Bali & Nusa Tenggara	4	Bali	Basri et al. (2025); Budihardjo (2019); Putri et al. (2022); Rajendra (2021)	Bali Aga House (Buleleng); *Puri* (palace); Bali Aga House (Bangli); Balinese Traditional House
	2	East Nusa Tenggara	Afifah and Kurniawan (2022) and Arisanti et al. (2022)*	Wae Rebo Village Traditional House and Sumba Traditional House
	4	West Nusa Tenggara	Julita and Hidayatun (2020)*; Sari et al. (2025); Sasongko et al. (2025); Zuryani (2019)	Sasak Traditional House (Lombok); *Lumbung* (rice barn); Sasak Traditional House (Lombok); Sasak Tribe Traditional Guest Houses
Java	5	Central Java	Cahyono et al. (2017); Muqoffa et al. (2024); Shofie and Prianto (2025); Xian et al. (2024), as well as Sardjono and Nugroho (2015)*	Joglo House [except for Muqoffa et al. (2024) with Saradan Traditional House in Wonogiri]
	1	East Java	Basri et al. (2025)	Tengger House
	2	West Java	Driknianto et al. (2024); Rajendra (2021)	Sundanese Traditional House; *Kampung* Mahmud Stilt House
	2	Yogyakarta	Rahmi (2017); Rini and Idham (2021)	Joglo and Limasan Houses
Kalimantan	2	South Kalimantan	Damayanti et al. (2017); Oktaviana et al. (2023)	Banjar House; Balai Padang House
Maluku & Papua	1	North Maluku	Rahim et al. (2021)	Moluccas Island Traditional House
	2	Papua	Putra et al. (2024)* and Widyastomo (2021)	Kampung Enggros and Kampung Tobati Traditional House; Sentani Traditional House (Jayapura)
Sulawesi	3	South Sulawesi	Aslam and Ridjal (2020); Lindarto and Defriza Harisdani (2024); Meldawati and Lottong (2016)	Bugis-Makassar Traditional House (*Kampung* Buntusu); Tongkonan House; Karampuang Traditional House
	2	South Sulawesi, relocated to DKI Jakarta & East Kalimantan	Artiningrum and Sukmajati (2017); Fadhilah and Safeyah (2025)	Bugis Tribe Traditional House

Regions	*n*	Provinces	Authors (Year)	Case Studies
	1	Southeast Sulawesi	Irmawati and Umar (2019)	Wakuru Local Market
Sumatra	2	Aceh	Nasution et al. (2020) and Yosantia et al. (2023)	Aceh Traditional House and Gayo House
	1	Jambi	Fadhilah et al. (2024)	Tuo House
	4	North Sumatra	Dafrina et al. (2022)*; Nasution et al. (2022); Rajendra (2021); Yusran and Dirgantara (2021)	Batak Bolon House [except for Nasution et al. (2022) with Melayu House]
	1	South Sumatra	Matondang and Sani (2021)	Lamban Pesagi House (Lampung)
	1	West Sumatra	Ermayanti et al. (2023)	Gadang House

Notes: Case studies are listed in the order of author names and publication year; ***n*** = number of case studies included; *) taken from Damayanti & Kusdiwanggo (2024)

RESULTS AND DISCUSSION

Resilience Of Indonesian Traditional Architecture: A National Overview

Challenging the view of traditional architecture as merely a rigid remnant of the past, this study argues that its survival against modern pressures is not a matter of passive preservation, but rather an active and intelligent process of resilience. The findings indicate that resilience is widely evident across the cases, though the process of adaptation is rarely straightforward. Instead, it often relies on practical compromises and, in a few critical instances, fails entirely, resulting in non-resilience.

According to Fig. 4, domains, the underlying pressures that trigger architectural transformation, are most often technical (39 cases) and social (38 cases), reflecting the widespread influence of material constraints, climate responsiveness, and shifting lifestyles. These frequently overlap with economic or organizational forces, forming hybrid pressures. For instance, in Sumba, the abandonment of ancestral beliefs (social) and rising costs of thatch as a traditional material (economic) led to the repurposing of sacred spaces and the adoption of zinc roofing (technical) (Arisanti et al., 2022). Comparable social–technical–economic interactions are evident in 17 of the 40 cases analyzed (refer to Fig. 4). Conversely, Bali's Pengotan village exemplifies one of 12 cases where social–technical interplay is reinforced by organizational forces, as customary law (adat) preserves traditional house layouts despite material or social change (Putri et al., 2022).

In response to these domain pressures, communities apply guiding principles, the strategies used to navigate change. The analysis shows a dominance of resourcefulness (35 cases) and robustness (26 cases) (see Fig. 4). Resourcefulness extends beyond creative use of materials to include spatial logic, builder know-how, and community labor (gotong royong). Robustness appears in both physical strategies, like floating timber columns or mortise joinery that withstand earthquakes (Afifah & Kurniawan, 2022), and in cultural resistance, as seen in the persistent core layout of Melayu houses in North Sumatra despite expanding family needs (Nasution et al., 2022). In 22 out of 40 cases, both principles operate in tandem: some maintain traditional forms and techniques where they remain effective (Afifah & Kurniawan, 2022; Yosantia et al., 2023), while others adapt by integrating modern materials when skilled labor or traditional resources become scarce (Arisanti et al., 2022; Fadhilah et al., 2024).

The application of these principles leads to varying resilience capacities across the 40 vernacular case studies examined: 37 are resilient (whether adaptive, absorptive, recovery-oriented, or a combination of these) and 3 are non-resilient. Among the resilient cases seen in Fig. 4, most exhibit adaptive-only capacity, occurring in 22 studies. This adaptiveness is reflected in layout reconfigurations (Putra et al., 2024; Sardjono & Nugroho, 2015), functional transformations (Ermayanti et al., 2023; Sari et al., 2025), material upgrades (Lindarto & Defriza Harisdani, 2024; Oktaviana et al., 2023), and modern installations such as air conditioning (Xian et al., 2024).

However, this dominance of adaptive capacity does not imply it is without consequence. In some cases, adaptations compromise cultural meaning, such as when the Sasak lumbung is transformed from a sacred grain store into tourist accommodation, preserving the building's physical survival but sacrificing its original meaning (Sari et al., 2025). Such examples remind us that resilience is not only about perseverance, but also the acceptance of certain compromises.

At the opposite end of this spectrum are the three cases where adaptation fails, resulting in non-resilience. These few cases show diverse kinds of breakdown in the adaptive process. Some are technical, such as the post-earthquake

rebuilding of Yogyakarta's Joglo houses, which weakened their structural integrity (Rini & Idham, 2021). Others are socio-cultural, such as the abandonment of the Dayak Balai Padang longhouse in favor of modern houses (Damayanti et al., 2017). In some instances, both technical and social factors contribute to decline. Oktaviana et al. (2023) exemplify this case by exploring how Banjar houses, though still inhabited, deteriorate through neglect and reliance on inexpensive modern materials, a pattern that undermines their capacity to adapt to change. Taken together, these cases underscore how neglected or misguided adaptations can lead to irreversible loss of heritage.

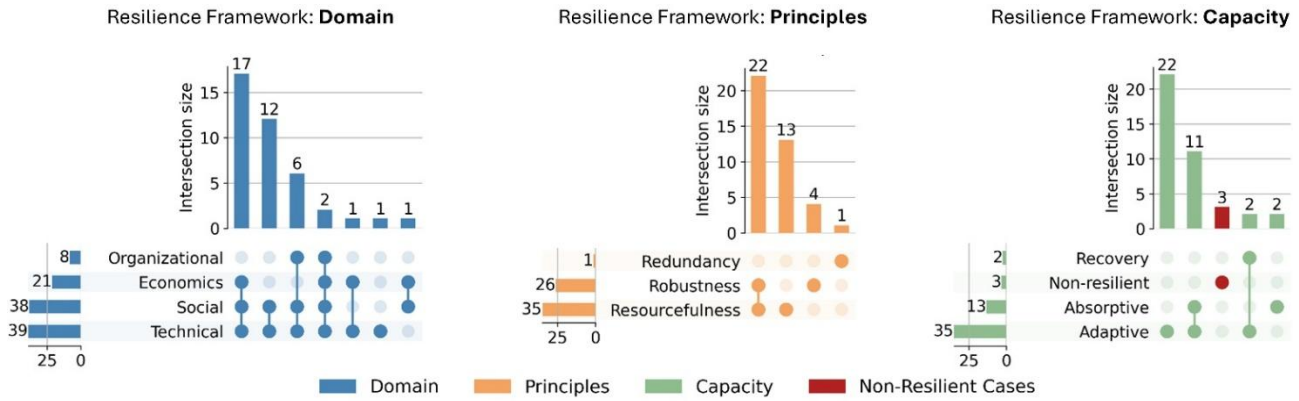


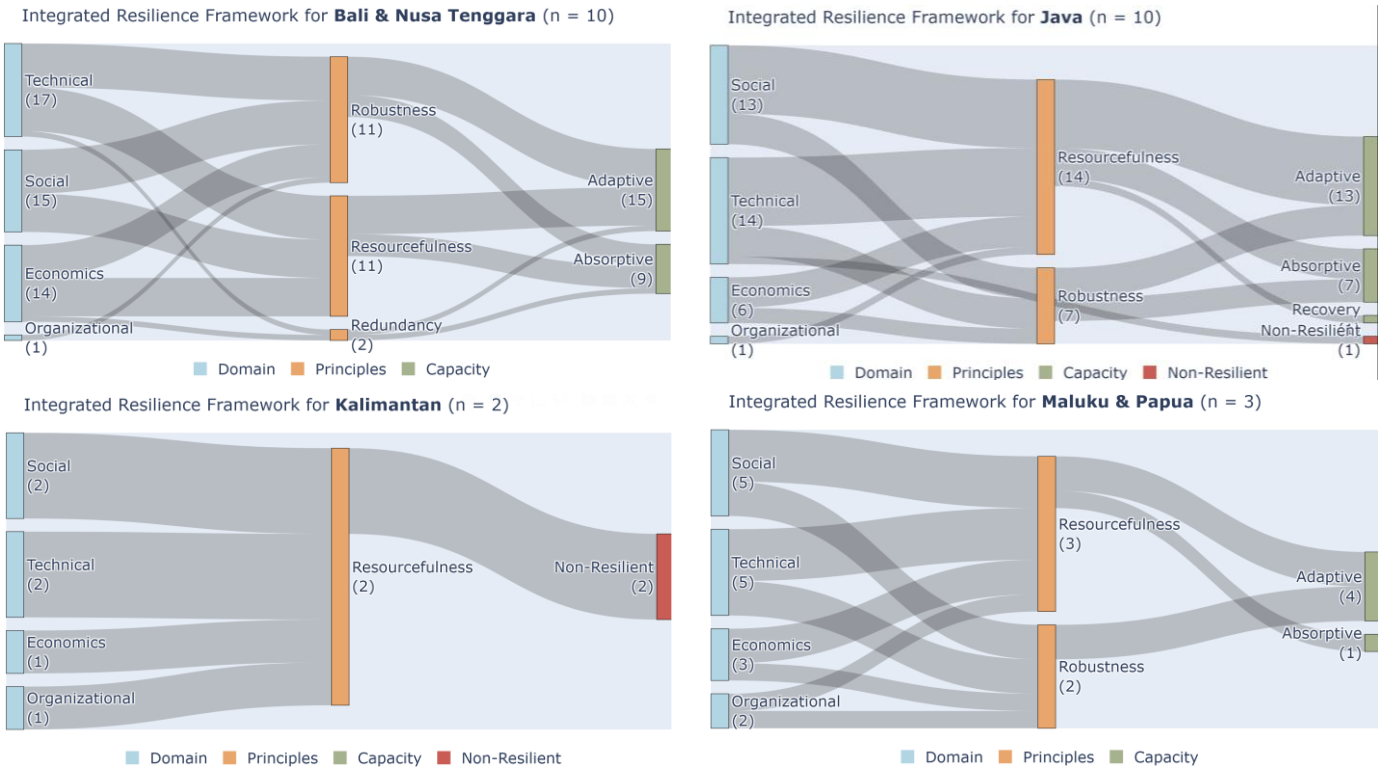
Fig. 4. Mapping Resilience Frameworks in Indonesian Architecture
(Source: Author)

Notes: Vertical bars show the number of cases with specific attribute combinations, while horizontal bars show the total frequency of each category; Horizontal bar totals may exceed the number of cases, as one case may reflect multiple attributes.

Contemporary Patterns Of Adaptation: A Thematic Analysis Across Regions

The following regional sections examine how various contexts influence resilience in Indonesia's traditional architecture. Instead of examining capacity, principles, or domains in isolation, this analysis traces their interplay, as shown in Fig. 5. While the figure illustrates how adaptive capacity dominates across the case studies, this does not imply that adaptation occurs uniformly throughout Indonesia. Variations in the observed resilience pathways indicate that both the form and expression of adaptation differ among regions, providing the basis for the insights discussed next.

Bali & Nusa Tenggara



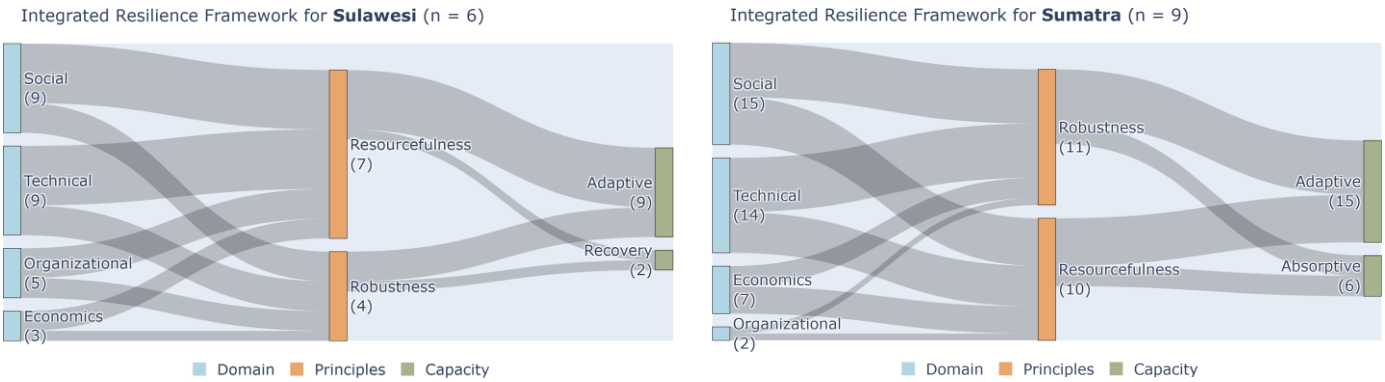


Fig. 5. Sankey Diagram of the Conceptual Framework Linking Domain, Principles, and Capacity in Each Group (Source: Author)

Notes: Flow thickness represents connection frequency, and the numbers on each node indicate total connection counts; ***n*** = the number of studies.

The rise of modern tourism, together with strong customary law (adat) practices, plays a significant role in shaping resilience adaptations in Bali and Nusa Tenggara. Tourism income not only provides financial support for preserving traditional architecture but also interacts with local social and cultural dynamics. This interaction demonstrates the robustness principle within the social domain, as communities remain firmly rooted in their customs despite external pressures. Adat restrictions, reinforced by tourists' appreciation of traditional aesthetics, generate resources that sustain architectural forms. This tourism–*adat* dynamic is evident in Puri Saren Agung Ubud, where funds from tourism support conservation with minimal alterations (Budihardjo, 2019). Similarly, Desa Pengotan enforces house preservation through *adat* law, while Bali Aga communities restrict modernization to non-sacred areas, keeping core spiritual spaces intact (Basri et al., 2025; Putri et al., 2022).

Another key resilience pattern in this region is the preservation of resourceful traditional materials, reflecting the technical domain and the principle of resourcefulness. Bamboo houses, for example, have proven highly effective in disaster contexts. During the 2018 Lombok earthquake, Sasak bamboo houses demonstrated exceptional seismic resilience due to their flexibility (Sasongko et al., 2025; Zuryani, 2019). However, economic pressures increasingly drive material substitutions, such as replacing breathable thatch with brick tiles or zinc roofing, which often compromise thermal comfort and reduce responsiveness to local climate conditions (Arisanti et al., 2022; Rajendra, 2021). These substitutions show that resilience is a negotiation between tradition, economy, and environment.

Java

The resilience of vernacular architecture in Java offers a clear example of how modernization shapes adaptive practices. Shifts in privacy, livelihood, and belief systems are key drivers of how households manage space. Rather than abandoning traditional layouts, families modified existing rooms by partitioning large halls into bedrooms (Sardjono & Nugroho, 2015). Fig. 6 illustrates the case study by Cahyono et al. (2017) on Javanese housing in Laweyan, Surakarta, which demonstrates adaptive transformation through successive changes in roof forms. These modifications addressed technical issues like leakage, reflected economic aspirations during the *batik* era's prosperity, and simplified maintenance for affordability. The evolution reflects resilience achieved through material resourcefulness, cultural reinterpretation, and the negotiation between heritage and practicality.

Similarly, Basri et al. (2025) highlight how spaces like the pawon in Tengger houses, initially used for cooking, are now repurposed as storage and gathering areas. In the same case, religious shifts also affect spatial use. Residents retain elements like the *padmasari* shrine physically but no longer use them for worship, reflecting a subtle yet meaningful adaptation to new belief systems.

Traditional Javanese architecture also demonstrates climate-responsive resilience using local construction expertise, with adaptations varying across regions. In Central Java's warmer lowland zones, high joglo roofs buffer heat and enhance ventilation (Muqoffa et al., 2024), while in the cooler West Java highlands, steep roof geometries help retain indoor warmth during cold nights to improve thermal comfort (Rajendra, 2021). These cases show that robustness in Javanese architecture lies not only in form but also in the continued application of traditional building knowledge, an essential part of resourcefulness.

Nevertheless, these adaptive strategies face new pressures as modern interventions enter the landscape. While materials such as concrete, ceramics, and zinc roofing may offer short-term convenience and maintain livability (Shofie & Prianto, 2025; Xian et al., 2024), they can still compromise long-term resilience. A more critical case is observed in Yogyakarta after the 2006 earthquake, when reinforced concrete was added to Limasan and Joglo houses

to increase their strength. As Rini and Idham (2021) reported, this hybrid disrupted the traditional timber system, whose flexibility had enabled seismic resilience. Instead of improving robustness, the modification weakened the houses' adaptive capacity and led to non-resilience. This analysis highlights that Java's vernacular architecture depends on whether modern adaptation stays rooted in traditional logic or drifts too far from it.

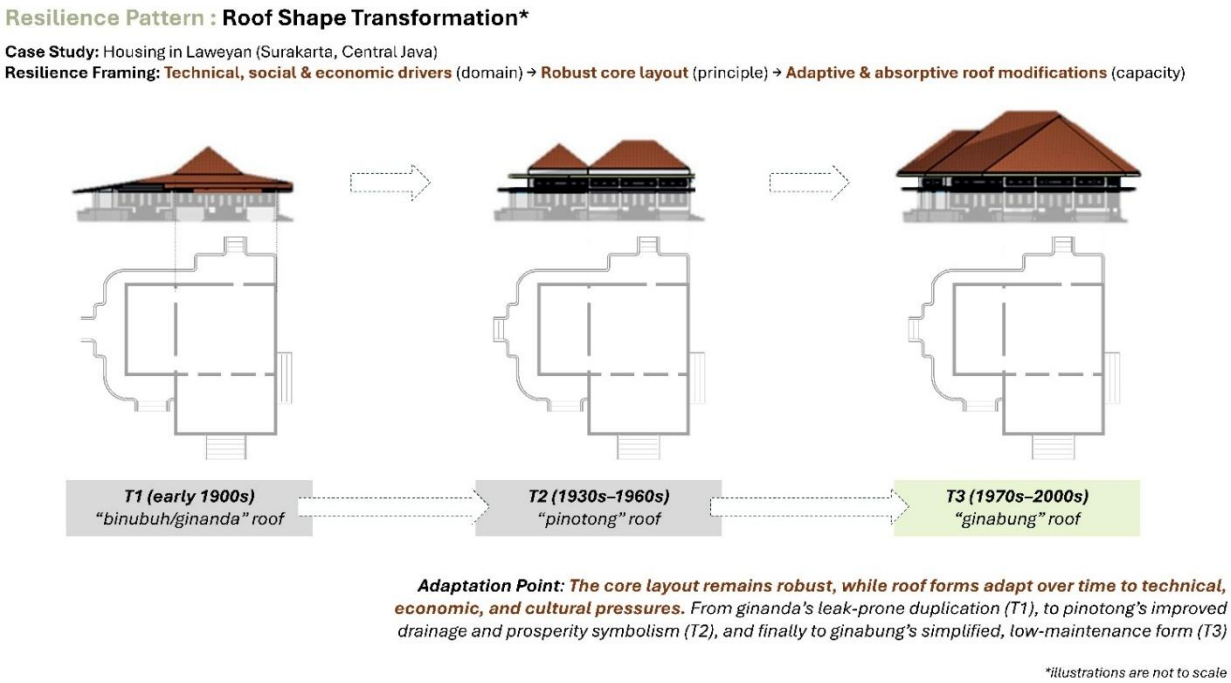


Fig. 6. Representative Resilience Pattern Illustrated Through Roof Shape Transformation in Java (Laweyan, Surakarta) (Source: Adapted from Cahyono et al. (2017))

Kalimantan

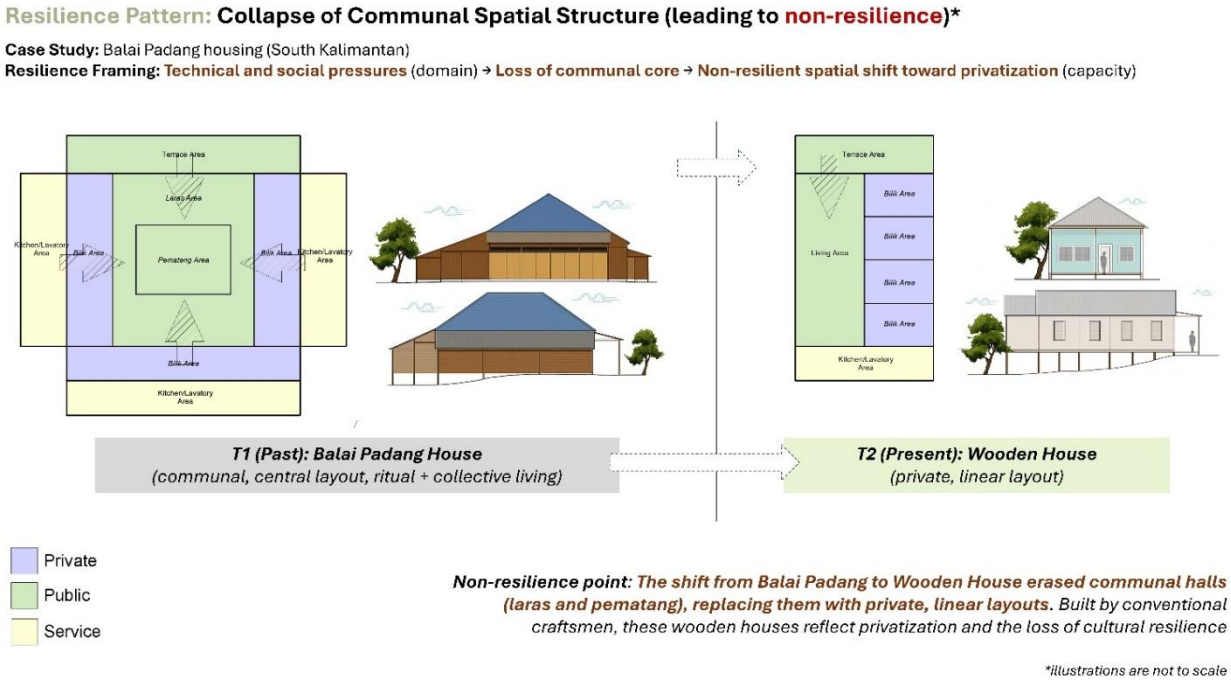


Fig. 7. Representative Non-Resilient Pattern through the Breakdown of Communal Spatial Structure in South Kalimantan (Balai Padang)
(Source: Adapted from Damayanti et al. (2017))

The resilience of vernacular architecture in Kalimantan, based on the Balai Padang (Damayanti et al., 2017) and Banjar (Oktaviana et al., 2023) case studies, demonstrates apparent failure to adapt to modern pressures (refer to Fig. 5). In Balai Padang, social transformations, particularly the increasing emphasis on privacy, have led to the

replacement of communal Balai spaces with private, linear single-family homes, as seen in Fig. 7. As residents seek to escape the noisy and crowded communal environment, the Balai's complex traditions and rituals fade, eroding its original social function. Meanwhile, in Banjar houses, a combination of technical, social, economic, and resourcefulness factors aggravate decline. Deteriorating elements are left unrepaired or covered with low-cost modern materials, a practice that accelerates decay and can result in the loss of major components or entire structures. These patterns reflect Schefold et al.'s (2004) observation that changing lifestyles often transform traditional architecture into hybrid forms, which lack original expression and lose resilience.

Maluku and Papua

The case studies from Maluku and Papua illustrate how vernacular architecture adapts differently to contemporary pressures, mainly in terms of resourcefulness, while maintaining resilience. Technically, Maluku retains strong continuity in traditional practices, with houses using locally sourced and affordable materials such as bamboo, wood, and sago fronds, combined with traditional joinery systems and passive design suited to the tropical climate (Rahim et al., 2021). In contrast, Papua has selectively adopted modern features, such as zinc roofing, glass windows, nailed joints, and simplified layouts, reflecting evolving household needs while still retaining key traditional forms (Putra et al., 2024; Widyastomo, 2021). Both approaches, whether entirely traditional or selectively modernized, support resilience by sustaining structural performance and climate responsiveness.

Another key pattern of resilience in this region emerges from the standpoint of social-resourcefulness. Both Maluku and Papua retain communal work (*gotong royong*) and spiritual rituals conducted before or during building phases, reinforcing social cohesion and traditional knowledge (Rahim et al., 2021; Widyastomo, 2021). In Papua, however, these community-based mechanisms are beginning to face risks as building processes begin to shift toward formalized, efficiency-driven approaches involving hired labor (Widyastomo, 2021). Despite this trend, organizational factors such as customary law (*adat*) in Kampung Enggros and Tobati, Jayapura, continue to enforce spatial preservation, helping houses remain robust even as other traditional practices wane (Putra et al., 2024).

Sulawesi

Diverse pressures, including cultural change, displacement, and institutional influence, shape vernacular resilience adaptations in Sulawesi. Case studies in this region stand out because they capture both inland communities and coastal resettlements shaped by migration. Inland groups, such as the Toraja, Karampuang, and Bugis-Makassar (Kampung Buntusu), preserve symbolic hierarchies, maintain customary spaces, and favor traditional materials, even as they adapt their buildings to modern needs (Aslam & Ridjal, 2020; Lindarto & Defriza Harisdani, 2024; Meldawati & Lottong, 2016). This socially rooted resourcefulness allows communities to sustain cultural identity while adapting to change.

Relocated communities, by contrast, must negotiate new environmental and social conditions. Bugis settlers in Kamal Muara (DKI Jakarta) and Balikpapan (East Kalimantan) show remarkable determination to preserve their cultural identity by reconstructing traditional houses in new locations. However, practical constraints, such as flooding risk and limited access to traditional materials, necessitate structural modifications and material substitutions, including concrete, ironwood, and factory-made components (Artiningrum & Sukmajati, 2017; Fadhilah & Safeyah, 2025). While these adaptations strengthen structural resilience, they can erode cultural values: sacred spaces are repurposed, symbolic elements removed, and government regulations increasingly influence design decisions. Still, despite these challenges, the communities manage to maintain the essence of their traditional homes.

Sumatra

In Sumatra, resilience in vernacular architecture is shaped by environmental risks, particularly earthquakes, as well as resourcefulness, changes in livelihoods, and evolving privacy needs. Traditional houses have long mitigated seismic hazards through elevated floors, earthquake-resistant joinery, and indigenous construction techniques, reflecting deep technical knowledge embedded in local forms (Aslam & Ridjal, 2020; Lindarto & Defriza Harisdani, 2024; Meldawati & Lottong, 2016). These traditional measures are often preserved because they remain effective today. The resourcefulness principle, evident in six of the nine documented cases, appears in the use of local, affordable materials, the retention of traditional layouts, and the continuation of communal construction practices.

Livelihood changes have also prompted spatial adaptations. The underfloor (*kolong*), once used to protect against wildlife that is now rare due to habitat loss, is now converted into living areas (Fadhilah et al., 2024), or, in the Aceh case study by Yosantia et al. (2023), into storage and livestock spaces that support the region's primary professions in farming and fishing. Other than that, Fig. 8 illustrates how the Melayu vernacular house in North

Sumatra (Nasution et al., 2022) follows this adaptive trajectory, evolving from a compact layout to expansions with new bedrooms, indoor bathrooms, and extended kitchens. These changes accommodate larger families and modern needs while maintaining the core public-private spatial hierarchy of traditional layouts.

Nonetheless, modernization in the Sumatra region introduces new pressures, creating tensions between preservation and change. Shifts toward tourism have transformed traditional homes into accommodations (Ermayanti et al., 2023), and shifting cultural and functional needs have transformed formerly communal layouts into private, segmented rooms (Fadhilah et al., 2024; Nasution et al., 2022; Yusran & Dirgantara, 2021). Economic constraints further drive the adoption of modern materials like concrete and zinc, sometimes compromising thermal comfort, cultural meaning, or structural integrity (Rajendra, 2021). Overall, Sumatra's traditional architecture remains resilient, but its durability now relies as much on flexibility and adaptive practices as on its original structural and cultural forms.

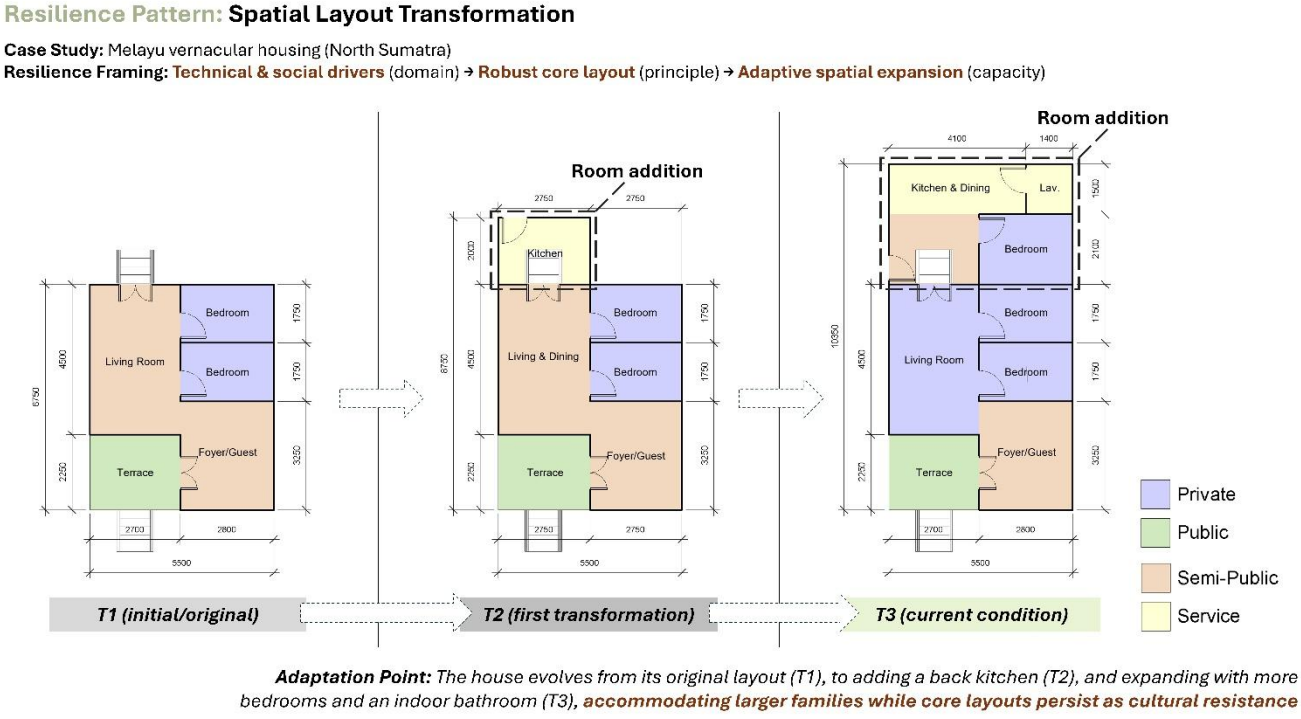


Fig. 8. Representative Resilience Pattern Illustrated through Spatial Layout Transformation in North Sumatra (Source: Adapted from Nasution et al. (2022))

Regional Analysis Summary

The three representative case illustrations presented in the regional sections (Java, Kalimantan, and Sumatra) depict contrasting resilience trajectories, distinguishing between successful adaptive responses and non-resilient breakdown. These include incremental adaptation in Java (Fig. 6), the breakdown of communal spatial structure in Kalimantan (Fig. 7), and adaptive spatial transformation in Sumatra (Fig. 8), illustrating how resilience is unevenly manifested across different socio-spatial contexts. Rather than providing comprehensive visual coverage of all regions, these cases are presented as illustrative examples of dominant and contrasting patterns emerging from the cross-regional synthesis. Building on these visual cases, Table 3 situates the illustrations within broader regional patterns, showing that resilience in Indonesian vernacular architecture emerges through diverse strategies shaped by environmental, social, technical, and organizational pressures.

Adaptive capacity dominates in most regions, yet mechanisms and vulnerabilities differ. In case studies in Bali, Nusa Tenggara, and parts of Java, resilience is reinforced through cultural institutions such as *adat*, tourism-driven resource generation, and the continuity of traditional construction knowledge. However, some extreme interventions in Java reveal non-resilient outcomes. Meanwhile, for the case studies in Sulawesi, Maluku, and Papua, resilience combines selective modernization with social and organizational domains, preserving functionality while adapting to new contexts. By contrast, Kalimantan's cases illustrate outright failure to adapt, where both social and technical systems have collapsed. Overall, resilience emerges not as uniform preservation of form, but as a strategic balance between maintaining cultural-technical continuity and accommodating evolving environmental and socio-economic conditions.

Table 3. Overview of Regional Case Studies

Regions	*n*	Key Domains	Guiding Principles	Main Adaptation Logic	What Remains	Capacity Types	Risks/Tensions
Bali & Nusa Tenggara	10	Technical, Social	Resourcefulness, Robustness	Preservation supported by tourism and selective modernization constrained by *adat*	Sacred spatial forms, bamboo structures, ritual zones	Mixed (Adaptive & Robustness)	Thermal discomfort, commodification, partial material substitution
Java	10	Technical, Social	Resourcefulness	Functional reconfiguration, climate-responsive strategies, and selective material innovation	Spatial hierarchy, passive design, builder knowledge	Adaptive (with some failure/non-resilience)	Disconnection from traditional practices, compromised thermal/structural performance
Kalimantan	2	Technical, Social	Resourcefulness	Spatial individualization, material substitution, neglect under economic/social pressures	Select symbolic cultural elements (e.g., *tawing halat*), partial structures	Non-resilient	Architectural degradation, loss of communal function, and complete failure to adapt
Maluku & Papua	3	Social, Technical, Organizational	Resourcefulness, Robustness	Retention of traditional practices (Maluku) and selective modernization (Papua)	Joinery methods, ritual practices, spatial customs, and symbolic elements	Adaptive	Community fragmentation, risk of weakening social mechanisms, and selective material substitution
Sulawesi	6	Social, Technical, Organizational	Resourcefulness, Robustness	Culturally anchored reinterpretation (inland), structural adaptation with relocation (migrants)	Symbolic forms, spatial logic, and some sacred elements	Mixed (Adaptive & Robustness)	Cultural erosion, over-regulation, and displacement vulnerability
Sumatra	9	Technical, Social	Resourcefulness, Robustness	Structural and spatial flexibility in response to environmental and livelihood pressures	Elevated floors, mortise joinery, symbolic hierarchy	Mostly Adaptive	Cultural dilution, low-quality material substitution, and modernization pressures

Notes: The column '***n***' refers to the number of case studies included.

CONCLUSION

This study finds that traditional architecture in Indonesia has undergone various changes and transformations. It continues to adapt to shifting social, cultural, and environmental demands. Communities modify forms, materials, and layouts, often making practical compromises to retain climate-responsive design logic and cultural symbolism. This process reflects resilient continuity, in which traditional buildings evolve to remain functional and meaningful.

Patterns of resilience emerge across 40 case studies from Bali and Nusa Tenggara, Java, Maluku, Papua, Sulawesi, and Sumatra. Adaptation strategies balance tradition with necessity, for example, retaining structural systems and decorative elements while selectively substituting materials due to environmental or social constraints. However, some cases, notably in Kalimantan and an isolated example in Java, show adaptive breakdowns where inappropriate repairs, material substitutions, or social disconnection accelerate architectural decline.

It must be acknowledged, however, that the limited scope and availability of case studies shape these findings. Some regions are better represented in academic literature than others, which can affect how patterns of resilience, or their absence, are perceived. The conclusions presented here, therefore, reflect the best evidence currently

accessible, rather than a comprehensive account of all vernacular traditions in Indonesia. Future research should address these gaps through more inclusive documentation, particularly in areas like Kalimantan and parts of eastern Indonesia.

Broadly, resilience in vernacular architecture does not mean keeping buildings unchanged, but navigating compromises that allow them to remain functional, culturally meaningful, and adaptable. Without sustained support from communities, institutions, and technical expertise, vernacular traditions risk becoming hollow symbols. With such support, however, they can continue evolving without losing their essence.

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