ISSN: 2029-7955 / eISSN: 2029-7947

VILNIUS TECH
Vilnius Gediminas Technical University

JOURNAL of ARCHITECTURE & URBANISM

2026
Volume 50
Issue 2
Pages 127–142
https://doi.org/10.3846/jau.2026.25451

APPLYING SPATIAL ETHNOMATHEMATICS TO MAINTAIN THE CULTURAL VALUES OF BALINESE AND THAI TRADITIONAL HOUSES

Erwin Ardianto HALIM [1]✉, Eakachat JONEURAIRATANA [2], Visuwat MALAI [3], Klawkanlayaphon SAWATMONGKHONKUL [4], Yudita ROYANDI [5], Shirly Nathania SUHANJOYO [6]

[1,5,6] *Universitas Kristen Maranatha, Bandung, Indonesia*
[2,3,4] *Silpakorn University, Bangkok, Thailand*

Article History:
- received 29 November 2025
- accepted 9 July 2026

Abstract. This study investigates how the cultural values embedded in Balinese and Thai traditional houses can be analytically extracted and maintained within contemporary residential design through the lens of spatial ethnomathematics. Drawing on D'Ambrosio's ethnomathematics and Bishop's pan-cultural activities of locating and designing, the research treats vernacular dwellings as operational diagrams of cultural cosmology, foregrounding proportion, modularity, orientation, and spatial hierarchy rather than ornament alone. The analysis is operationalized through the IMO(E) framework – Inner (cosmology), Middle (social practice), Outer (geometric form), and (E)xperimental (transformation) – extending Leong and Clark's three-tier model of culture-based design. A practice-based qualitative methodology combines literature review, observation, typological-morphological reading, and design experimentation across two cases: the Balinese karang governed by Tri Hita Karana, Sanga Mandala, and Tri Angga; and the Thai ruean structured by hwang modularity, chan mediation, and stilt-based vertical cosmology. Findings demonstrate that spatial ethnomathematics, coupled with IMO(E), provides a methodological bridge that sustains cultural values not by replicating form but by maintaining the spatial-cosmological logic that form materialises. Applied to a contemporary two-storey residential proposal, the protocol shows how abstraction, substitution, and recombination carry Inner cosmology and Middle practice into Outer geometry while remaining responsive to present-day inhabitation.

Keywords: spatial ethnomathematics, IMO(E) framework, Balinese traditional house, Thai traditional house, cultural values, vernacular architecture, culture-based design.

✉Corresponding author. E-mail: ***erwin.ardianto@art.maranath.edu***

1. Introduction

The acceleration of globalization and urban modernization has placed the cultural identity of vernacular dwelling under sustained pressure across Southeast Asia. Traditional houses in Indonesia and Thailand – long shaped by cosmological orientation, social ritual, and tropical-climate adaptation – are increasingly displaced by standardized modern housing that prioritizes efficiency and stylistic novelty over the cultural meanings their forms once carried. The challenge addressed here is not the disappearance of buildings per se, but the attenuation of the cultural values that buildings transmit: worldview, ritual practice, social order, and the proportional-spatial logic by which a community inhabits its world (Rapoport, 1969; Oliver, 2006).

This study positions *spatial ethnomathematics* as an analytical lens through which the cultural values embedded in Balinese and Thai traditional houses can be made legible, transferable, and sustainable in contemporary design. Ethnomathematics, as proposed by D'Ambrosio (1985, 2006), reframes mathematics as culturally situated knowledge; its spatial turn (Bishop, 1991; Eglash, 1999) extends the analysis to how communities orient, measure, divide, and inhabit space. Read through this lens, the Balinese *karang* and the Thai *ruean* are not collections of vernacular motifs but operating systems of culturally-governed geometry – proportional, modular, oriented, and hierarchically ordered.

To structure this reading and connect it to design practice, the study employs the *IMO*(*E*) *framework* (Halim & Joneurairatana, 2024) – Inner, Middle, Outer, and (E)xperimental – an extension of Leong and Clark's (2003) three-tier model of culture-based design. The framework allows the study to move from cosmology (Inner) through social practice (Middle) and geometric form (Outer) into design transformation (E), thereby connecting ethnographic and spatial-ethnomathematical analysis to actionable design outcomes that sustain, rather than freeze, cultural value.

1.1. Research gap

Three gaps emerge from a critical review of the literature. *First*, although ethnomathematics has been productively applied to textile, ornament, and artifact analysis, its

Copyright © 2026 The Author(s). Published by Vilnius Gediminas Technical University

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (*http://creativecommons.org/licenses/by/4.0/*), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

spatial application to vernacular dwelling remains underdeveloped, particularly in Southeast Asian contexts where cosmological-spatial systems are demonstrably mathematical (Adam, 2004; Albanese & Perales, 2014). Existing studies frequently stop at the recognition of basic geometric primitives – squares, triangles, prisms – without engaging proportion, modularity, and hierarchy as integrated mathematical-cultural systems. *Second*, comparative studies of Balinese and Thai traditional houses tend to treat them as parallel ethnographic cases rather than as cognate spatial-ethnomathematical systems capable of cross-fertilization through shared structural principles. *Third*, existing culture-based transformation models rarely articulate an explicit, stratified protocol that traces design propositions from Inner cosmology through Middle practice into Outer geometry, leaving culture-based design vulnerable to the critique of stylistic eclecticism and surface mimicry.

1.2. Research questions

Responding to these gaps, the study addresses three research questions:

RQ1. What spatial-ethnomathematical systems – proportion, modularity, orientation, and spatial hierarchy – govern the Balinese and Thai traditional house, and what cross-cultural parallels emerge between them?

RQ2. How can the IMO(E) framework operationalize spatial ethnomathematics to translate Inner cosmology and Middle social practice into design-actionable Outer geometry?

RQ3. What transformation strategies enable contemporary residential design to maintain the cultural values of the Balinese and Thai house without resorting to literal replication?

1.3. Contributions

Responding to the three research questions above, the study delivers three contributions: (i) a *spatial-ethnomathematical reading* of Balinese and Thai traditional houses through the IMO(E) framework, foregrounding proportion, modularity, and hierarchy rather than ornament alone; (ii) a *comparative cross-cultural analysis* that identifies cognate structural logics between two Southeast Asian dwelling systems and articulates them as a shared design vocabulary; and (iii) a *stratified transformation protocol* that proceeds explicitly from Inner cosmology through Middle practice to Outer geometry and into Experimental synthesis, demonstrated through a contemporary two-storey residential design proposal.

1.4. Article structure

Section 2 reviews the conceptual foundations of spatial ethnomathematics, vernacular architecture as cultural-mathematical text, and the IMO(E) framework, and reads the Balinese and Thai houses as spatial-ethnomathematical systems. Section 3 describes the practice-based qualitative methodology. Section 4 presents the spatial-ethnomathematical analysis of the two cases across Inner, Middle, and Outer layers. Section 5 develops the (E)xperimental transformation model and applies it to a contemporary residential design. Section 6 concludes with implications for designers, educators, and cultural actors committed to maintaining vernacular cultural identity.

2. Literature review

2.1. Ethnomathematics

In this study, ethnomathematics is positioned as the conceptual intersection of three disciplinary fields: mathematics, cultural anthropology, and mathematical modeling, as illustrated in Figure 1. From mathematics, the framework draws formal concepts of measurement, proportion, and geometric relation; from cultural anthropology, it draws attention to how spatial and material practices carry symbolic and cosmological meaning within a community; and from mathematical modeling, it draws the analytical tools needed to translate observed vernacular patterns into quantifiable, comparable structures. Ethnomathematics thus provides the lens through which the spatial organization of the Balinese and Thai traditional houses can be read simultaneously as cultural practice and as an implicit, culturally embedded mathematical system.

The concept of *ethnomathematics* was introduced by D'Ambrosio (1985) to designate the mathematics practised by identifiable cultural groups, including national-tribal societies, labour groups, professional classes, and children of specific age brackets (d'Ambrosio, 1985, Figure 1). Rather than treating mathematics as a universal abstraction, ethnomathematics frames it as culturally situated knowledge – generated, transmitted, diffused, and institutionalised within particular contexts (D'Ambrosio, 2006). Subsequent scholarship has expanded this foundation. Ascher (1991) demonstrated how mathematical ideas are embedded in the artefacts and practices of non-Western societies, while Bishop (1991) identified six pan-cultural mathematical activities – counting, locating, measuring, designing, playing, and explaining – that frame all human engagement with quantitative and spatial reasoning (Ascher, 1991).

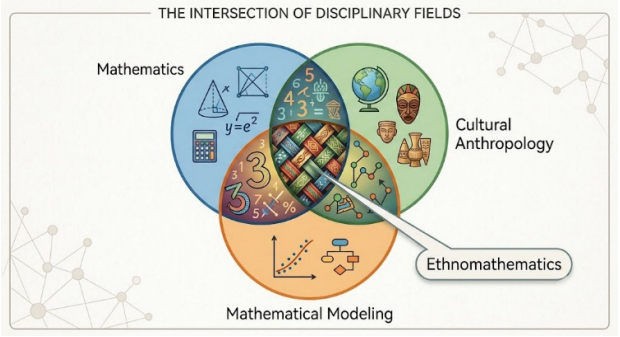

Figure 1. Ethomathematics as an intersection of three disciplines (source: Prahmana, 2022)

Among these activities, *locating* and *designing* forms the conceptual bridge between ethnomathematics and architecture. Locating concerns how communities orient themselves in space, navigate their environment, and structure cosmological order; designing concerns the imposition of form, proportion, and pattern on built objects (Bishop, 1991). Eglash's (1999) study of African fractals, which traced recursive geometric logic in settlement layouts and ornament, was pivotal in showing that vernacular spatial knowledge often encodes sophisticated mathematical relationships – not as conscious abstraction, but as embodied cultural practice (Eglash, 1999).

This spatial orientation within ethnomathematics has come to be referred to as spatial ethnomathematics: the analysis of culturally embedded mathematical structures that govern how communities conceive, measure, orient, divide, and inhabit space (Adam, 2004; Albanese & Perales, 2014; Massarwe et al., 2010). Spatial ethnomathematics extends beyond the recognition of basic geometric primitives – squares, triangles, prisms – to examine *proportion*, *modularity*, *orientation*, *spatial hierarchy*, *and symbolic order* as integrated mathematical-cultural systems. For vernacular architecture, this distinction is critical: the meaning of a triangular roof lies not in its triangularity, but in its proportional system, its directional alignment, and the cosmological narrative it materialises.

2.2. Vernacular architecture as mathematical-cultural text

Vernacular architecture has long been understood as a record of cultural adaptation. Birdwell-Pheasant's and Lawrence-Züniga's (1999) seminal *House Form and Culture* argued that house form is determined less by climate and material than by socio-cultural forces, worldview, kinship structures, ritual obligations, and conceptions of space (Birdwell-Pheasant & Lawrence-Züniga, 1999). Oliver (2006) similarly framed vernacular buildings as cultural artifacts that "meet needs" in environmentally, socially, and spiritually integrated ways (Oliver, 2006). Glassie and Truesdell (2008) extended this line by reading vernacular dwellings as *texts*: legible expressions of cultural logic, whose grammar can be reconstructed through systematic comparison.

Read through the lens of spatial ethnomathematics, vernacular houses emerge as more than texts – they become *operational diagrams* of cultural cosmology. The proportional system of a Balinese *karang* (houseyard), the orientation logic of a Thai *ruean*, the modular logic of stilted-floor heights, and the directional layout of pavilions all constitute mathematical-cultural statements. Typomorphology (He & Qi, 2019; Wolfrum & Janson, 2019) provide methodological grounding for tracing these relationships, treating the building not as an isolated object but as a transformation of a deeper structural type. This positions the present study within a tradition that reads vernacular form as the visible product of culturally governed mathematical operations.

2.3. The IMO(E) framework as an analytical lens

To operationalise spatial ethnomathematics within architectural analysis, this study employs the IMO(E) framework – Inner, Middle, Outer, and (E)xperimental – an extension of Leong and Clark's (2003) three-tier model of culture-based design, developed by Halim et al. (2023) for the analysis of *cultural carriers* in vernacular and product design contexts.

Leong and Clark (2003) originally proposed a three-layer reading of cultural objects: an Outer ("tangible") layer of physical form, material, and visible ornament; a Middle ("behavioural") layer of usage, ritual, and social practice; and an Inner ("intangible") layer of belief, worldview, and meaning. The framework was developed to guide designers in moving beyond surface mimicry of cultural form toward design that carries deeper cultural significance. However, the original model addresses interpretation rather than creation: it explains how to *read* cultural objects but offers limited guidance for *generating* new artefacts from cultural sources (Leong & Clark, 2003).

The IMO(E) framework extends this model by adding an Experimental (E) layer – a transformational stage in which Inner–Middle–Outer findings are recombined, abstracted, and translated into new design propositions. The (E) layer is where ethnographic and spatial-ethnomathematical analysis become design action. In the present study, the four layers are operationalised as set out in Table 1.

Table 1. Operationalization of the IMO(E) framework in this study (source: developed by author after Leong & Clark, 2003; Halim & Joneurairatana, 2024)

Layer	Domain	Application in this study
Inner	Cosmology, belief, philosophy	Tri Hita Karana, Nawa Sanga, Tri Angga (Bali); Theravada cosmology, ancestral-spirit beliefs, river-orientation worldview (Thailand)
Middle	Social practice, ritual, daily use	Spatial hierarchy of bale within the karang; communal use of the chan and grouped ruean; ritual circulation patterns
Outer	Geometric form, proportion, and material	Roof typologies, stilt proportions, modular plan units (hwang), ornamental geometry, material articulation
(E)xperimental	Transformation, recombination	Translation of Inner–Middle–Outer findings into contemporary residential design through abstraction, substitution, and recombination

By coupling spatial ethnomathematics with IMO(E), this study moves beyond the identification of basic shapes – the Outer layer alone – toward a stratified analysis that connects geometric form to social practice and cosmological order. This addresses a recurring critique of architectural ethnomathematics: that it too often stops at form recognition without engaging the cultural-semantic systems in which form is embedded (Albanese & Perales, 2014). Within the present study, the (E)xperimental layer further provides the methodological space in which transformation strategies – abstraction, substitution, infill, and recombination – can be applied systematically rather than intuitively.

2.4. Balinese and Thai houses as spatial-ethnomathematical systems

The objects of this study are the traditional houses of Bali and Thailand, presented in Figure 2. Both typologies were selected as comparative cases because each encodes spatial reasoning — orientation, proportion, and hierarchical zoning — governed by cosmological and socio-cultural principles rather than formal geometric instruction. The Balinese house (Figure 2a) reflects a cosmologically hierarchical spatial order, while the Thai house (Figure 2b) reflects a spatial order shaped by climatic adaptation and cultural convention; both carry implicit, quantifiable systems of measurement embedded in vernacular practice. Comparing the two allows the study to examine how spatial-ethnomathematical reasoning manifests across culturally distinct but typologically comparable traditional dwellings.

Balinese traditional architecture (Figure 2a) is governed by an interlocking set of cosmological-spatial principles codified in vernacular treatises such as the *Asta Kosala-Kosali* and *Asta Bhumi* (Adnyana et al., 2021; Gelebet, 2002; Kumurur & Damayanti, 2009). *Tri Hita Karana* – literally the three causes of well-being – establishes the threefold harmony between human and the divine (*parahyangan*), human and human (*pawongan*), and human and nature (*palemahan*) as the philosophical foundation of dwelling (Ardiana et al., 2026; Roth & Sedana, 2015; Solihin & Sumawidari, 2021). On the scale of the dwelling, the philosophy is operationalized through three interlocking spatial schemes. *Sanga Mandala* divides the *karang* into nine zones along a sacred–profane gradient oriented to the kaja–kelod axis toward Mount Agung, the cosmological center (Pradnyasari, 2017; Riyanto & Bhattacarya, 2022; Samadhi, 2004; Suryada & Bagus, 2012). *Tri Mandala* establishes the threefold zoning – *utama* (upper, sacred), *madya* (middle, human), *nista* (lower, profane) – that maps Tri Hita Karana onto a territorial geometry (Mildawani et al., 2024; Nurmala et al., 2025). *Tri Angga* organizes every built element – from the *karang* down to a single *bale* – into a tripartite head–body–foot hierarchy, with the central courtyard or *natah* functioning as the cosmological midpoint that anchors the dwelling to Tri Hita Karana (Sulistyawati et al., 2008; Parwata, 2011). These are not abstract metaphysics; they are mathematical operations: a 3×3 grid, an axial orientation, a proportional tripartition, and a culturally-calibrated measurement system based on the body of the owner (*musti*, *depa*, *hasta*). Read through spatial ethnomathematics, Balinese vernacular architecture constitutes a system of culturally-governed geometry in which philosophical order is materialized as spatial measure.

Thai traditional architecture exhibits a comparable but distinct logic. The *ruean* (house) is composed of modular bays – *hwang* – whose proportions follow standardized ratios derived from human scale and material constraint (Chuapram et al., 2012; Sathāpitānon & Mertens, 2012) (Figure 2b). The *chan* (semi-outdoor veranda) constitutes both a climatic device and a spatial-social regulator, mediating the threshold between private and communal life (Chiranthanut, 2020; Pintong, 2017). The stilted floor encodes a vertical cosmology in which the under-floor (ground/spirits), living floor (humans), and roof (sacred/ancestral) replicate a layered three-world structure resonant with Theravada cosmology. Roof pitch, eave projection, and gable termination (*ngao*, *panlom*) follow proportional conventions that combine ritual symbolism with tropical-climate performance (Tengkaoprasert, 2018).

Both traditions, then, are not merely sources of decorative motifs but operating systems of spatial-cultural mathematics. This positions them as appropriate cases for IMO(E)-based transformation analysis: the Inner layer is rich and well-documented; the Middle layer is observable in continuing practice; the Outer layer is geometrically explicit; and the cross-cultural parallel between the two systems offers an analytic ground for the (E)xperimental transformation that follows.

a) b)

Figure 2. Traditional house object research: a) Balinese traditional house; b) Thailand traditional house (Source: a) Ministry of Tourism, Republic of Indonesia 2026; b) Sathāpitānon & Mertens, 2012)

2.5. Design transformation and cultural continuity

The transformation of vernacular spatial knowledge into contemporary architecture has been debated extensively. Antoniades et al. (1992) framed transformation as a generative process operating through identifiable strategies – including *abstraction*, *substitution*, *layering*, and *recombination* – that allow architects to engage source material without resorting to literal replication (Frampton et al., 1980). *Critical regionalism* offered a parallel argument: that meaningful contemporary architecture must mediate between universal modernity and place-specific culture without collapsing into pastiche or nostalgic mimicry.

Within this discourse, the concept of *cultural sustainability* (Throsby, 1999) frames cultural value as a forward-looking project of continuity through change. The emphasis falls on *maintaining cultural meaning* rather than freezing form: heritage value is sustained not by literal reproduction of the historic object but by carrying forward the cultural logic – cosmological, social, and spatial – that the object materializes. This orientation aligns with the broader policy turn toward intangible cultural value, as reflected in international cultural policy instruments, and is consistent with the goal of cultural continuity in living design practice.

In this context, the present study positions spatial ethnomathematics operationalized through the IMO(E) framework as a methodological bridge between vernacular cultural knowledge and contemporary design practice. The Balinese and Thai houses are treated as *cultural carriers* whose Inner–Middle–Outer logic can be analytically extracted and experimentally re-deployed in contemporary residential design. This approach extends the discourse from form-based reproduction toward what Halim and Joneurairatana (2024) term *culture-based transformation*, in which cultural values are sustained as living design knowledge.

3. Method

The research adopts a practice-based, qualitative approach (Gherardi, 2000; Joneurairatana, 2021) that integrates ethnographic interpretation with design experimentation. The study is structured as a stratified protocol aligned with the IMO(E) framework, so that the data collection, analysis, and synthesis stages each correspond to a layer of cultural-spatial reading and, ultimately, to a design transformation.

Data were collected through four complementary techniques. First, a structured literature review consolidated cosmological-philosophical sources (Inner), ethnographic descriptions of dwelling practice (Middle), and morphological documentation of building elements (Outer) for both the Balinese *karang* and the Thai *ruean*. Second, field observation and documentation of representative cases provided geometric, proportional, and material evidence for the Outer layer. Third, semi-structured engagement with documented practitioners' accounts and prior interview material informed the Middle layer. Fourth, design experimentation – sketching, three-dimensional modeling, and iterative refinement – served as the (E)xperimental phase in which the protocol generated and tested transformation propositions (Halim & Joneurairatana, 2024).

3.1. Stages of research

The research proceeded through six sequential stages:

- Identification and ethnographic reading of the Balinese and Thai traditional house – mapping cosmological principles and social practices that constitute the Inner and Middle layers;
- Case-study observation – documenting Outer-layer geometry: typologies, proportions, modularity, and material articulation;
- Spatial-ethnomathematical analysis – extracting basic geometric primitives, then proportional, modular, and hierarchical systems for each case, and identifying cross-cultural parallels;
- Transformation strategy formulation – selecting abstraction, substitution, layering, and recombination strategies from (Antoniades et al., 1992), aligned to each spatial-ethnomathematical finding;
- Design experimentation – generating and iteratively refining contemporary residential proposals in two-dimensional plans, three-dimensional models, and axonometric views;
- Reflective evaluation – assessing the resulting design against criteria of cultural continuity, spatial coherence, climatic responsiveness, and architectural identity, and articulating implications and recommendations.

The geometric examination of the Balinese *karang* and the Thai *ruean* was conducted to identify their characteristic primitives and proportional systems, as well as the modular and hierarchical operations through which these primitives are composed. Modern houses that have undergone renovation or experimental redesign were selected as objects of the transformation phase, because their formally malleable elements – especially roofs and stilted ground levels – offer productive surfaces for integrating the spatial-ethnomathematical findings derived from the two traditional cases. Tracing, modular subdivision, and recombinatorial geometry were used as core techniques in the (E)xperimental phase to translate Inner and Middle findings into Outer form (Figure 3).

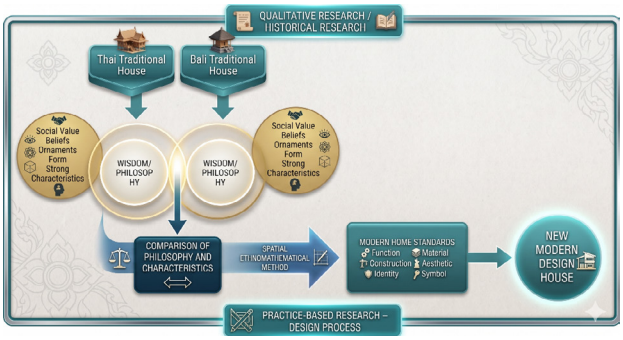

Figure 3. Research thinking framework (source: developed by the author)

4. Results and discussion: spatial-ethnomathematical analysis

This section presents the spatial-ethnomathematical reading of the two cases through the Inner–Middle–Outer layers of the IMO(E) framework. The analysis foregrounds proportion, modularity, orientation, and spatial hierarchy as integrated mathematical-cultural systems, rather than treating the cases as inventories of basic shapes alone. Section 4.1 introduces the two cases. Sections 4.2 and 4.3 develop the spatial-ethnomathematical analysis of the Balinese and Thai houses, respectively. Section 4.4 synthesizes the cross-cultural parallels that prepare the ground for the (E)xperimental transformation in Section 5.

4.1. Case studies: Balinese and Thai traditional houses

Two cases are considered in parallel: the Balinese traditional house from Indonesia and the Thai traditional house from Thailand. The two were selected because they share cosmological and climatic conditions – both sit within tropical Southeast Asia, and both organize dwelling around an integrated spiritual–social–environmental scheme, while expressing this shared orientation through distinct spatial-ethnomathematical systems. The comparative pairing makes cognate structural logics visible while preserving the specificity of each tradition.

The Balinese *karang* (houseyard) is composed of multiple pavilions, the bale, arranged around an open courtyard (Figure 4). The layout follows a strict hierarchical organization, distinguishing spaces for family life, religious ritual, and social activity, with a household temple typically located in the most sacred zone of the compound (Gelebet, 2002; Halim, 2016; Dwijendra, 2008). The household compound is read by the community as a representation of the Hindu cosmological scheme that frames the human body (*bhuana alit*) as a microcosm of the larger universe (*bhuana agung*), and is built under the guidance of the *Asta Kosala-Kosali* manuscripts that translate cosmological order into spatial proportion and measure (Parwata, 2011). The principal philosophical-spatial principles that govern the Balinese house are *Tri Hita Karana*, *Tat Twam Asi*, *Tri Angga*, and *Sanga Mandala* (Mildawani et al., 2024; Peters, 2013; Samadhi, 2004; Solihin & Sumawidari, 2021; Wastika, 2005).

Figure 4. Isometric view of the traditional Balinese *karang* (source: Ferschin et al., 2013)

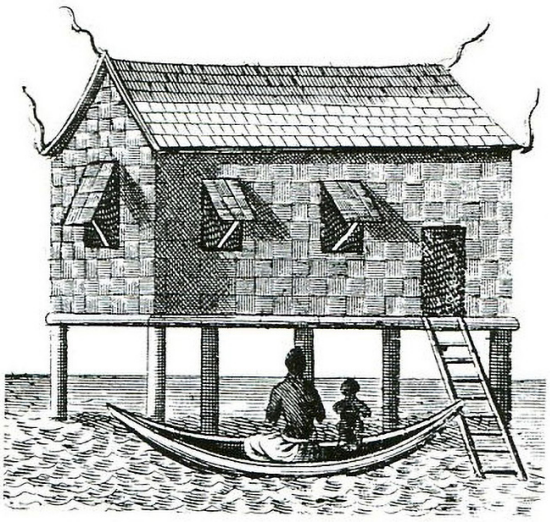

Figure 5. Traditional Thai *ruean* (source: Pintong, 2017)

The Thai *ruean* was historically embedded in a riverine landscape in which the waterway functioned simultaneously as a transport, irrigation, and social resource (Figure 5). Early Thai settlements clustered along riverbanks, and the relationship between households and water remains visible in rituals such as *Loy Krathong*. Traditional Thai architecture was developed with deliberate sensitivity to climate and lifestyle. Houses were elevated on high stilts to accommodate seasonal flooding, multi-level flooring distinguished functional zones, plank flooring permitted under-floor ventilation, and steeply pitched roofs with wide eaves drained heavy tropical rains while shading the building envelope. Regional variants from the North, Northeast (Isan), Central plain, and South display this shared structural logic in materially specific ways, calibrated to local climate, materials, and lifeways.

Within the Thai tradition (Figure 6), the spatial-architectural identity of the *ruean* is anchored in two recurrent features: the modular *hwang* bay system and the *chan*, a semi-outdoor veranda that constitutes both a climatic device and a social regulator. Sathāpitānon and Mertens (2012) summarise the distinguishing characteristics of the traditional Thai house as follows: a stilted lower level used for daily activity, storage, and boat mooring during flood; one to six bay units (hwang), often doubled at the end elevation; high gable roofs with long overhanging eaves that protect the dwelling from rain and sun while permitting heat convection; inward-sloping diaphragm walls with permeable elements that promote ventilation, especially in the kitchen; and a large veranda or *chan-baan* that accounts for an average of around sixty per cent of the floor area (Sathāpitānon & Mertens, 2012; Figure 7).

Figure 6. The Red Palace (Tamnak Daeng), Bangkok National Museum, exemplifying early Rattanakosin Thai residential architecture (source: Arunoprayote, 2022)

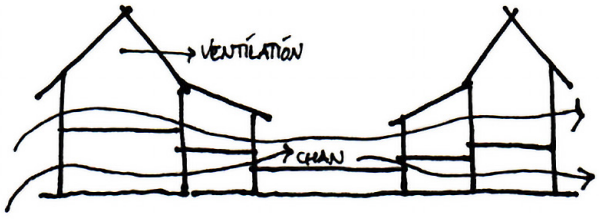

Figure 7. Single *ruean*, grouped *ruean* cluster, and central-region courtyard arrangement, illustrating modular composition and ventilation logic (source: modified from: Arunoprayote, 2022, drawing by Klawkanlayaphon, 2024)

4.2. Spatial-ethnomathematical reading of the Balinese house

4.2.1. Inner layer: cosmological geometry

The Inner layer of the Balinese house is structured by four cosmological-spatial principles that operate as mathematical schemes (Dwijendra, 2008; Peters, 2013). *Tri Hita Karana* establishes a threefold relational geometry between human and the divine (*parahyangan*), human and human (*pawongan*), and human and nature (*palemahan*), and is operationalized across the dwelling through the placement of the family shrine, the social pavilions, and the cultivated yard (Mildawani et al., 2024; Samadhi, 2004; Wastika, 2005). *Tri Angga* imposes a tripartite vertical hierarchy – head, body, foot on every spatial element, from the entire karang down to a single bale (Parwata, 2011). *Sanga Mandala* produces a 3×3 grid in which the *karang* is divided into nine zones along a sacred–profane gradient oriented to the kaja–kelod axis (toward and away from Mount Agung) (Aryani & Tanuwidjaja, 2013; Taş & Özcan, 2023). *Nawa Sanga* adds an eight-directional plus center cosmological scheme that aligns specific divinities with cardinal and intercardinal orientations, while the central courtyard (*natah*) anchors the composition as the cosmological midpoint (Solihin & Sumawidari, 2021). Together these principles constitute a culturally-governed coordinate system that integrates axial orientation, gridded subdivision, and proportional tripartition into a single operative geometry of dwelling. Read through spatial ethnomathematics, Tri Hita Karana functions not only as a metaphysical statement but as the generative grammar from which the dimensional, proportional, and orientational rules of the Balinese house are derived.

4.2.2. Middle layer: social and ritual practice

The Middle layer translates the Inner geometry into daily and ritual practice. The arrangement of pavilions (*bale*) within the *karang* assigns specific social functions – family living, ritual, kitchen, granary, ancestral shrine – to specific zones of the Sanga Mandala grid. Circulation across the *karang* follows the *kaja–kelod* orientation, so that movement through the household enacts the sacred–profané gradient. Ritual practice, from daily offerings to life-cycle ceremonies, is staged across the gridded compound, ensuring that the Inner cosmological order is performed rather than merely depicted. The Middle layer, therefore, functions as the lived operationalization of the Inner mathematical-cultural scheme.

4.2.3. Outer layer: geometric form and proportion

The Outer layer materializes the Inner and Middle systems in a concrete geometric form. Table 2 summarises the basic geometric primitives identifiable in the Balinese case; these primitives are then composed through the proportional and hierarchical operations described above.

In addition to these primitives, the Balinese case exhibits three composed mathematical operations that constitute its spatial-ethnomathematical signature. First, the 3×3 Sanga Mandala grid governs the plan, distributing pavilions according to a hierarchical lattice. Second, Tri Angga produces a head–body–foot tripartition of every vertical element. Third, the recombination of the cube (walls), triangular prism (roof), and cylinder (pillar) is consistently composed under a proportional discipline derived from human scale and cosmological orientation. The geometry that is visually legible at the Outer layer – squares, triangles, prisms, limas, and cylinders – derives its cultural meaning from the gridded, axial, and tripartite operations imposed by the Inner layer.

Table 2. Exploration of basic geometric forms in the Balinese karang (source: developed by author)

No	Original shape	Original visual	Dominant visual elements	Basic geometric form
1.	Full karang		Compound plan + pavilions + courtyard	Rectangle, square, gridded composition
2.	Bale meten		Walls and floor plate	Cube + beam
3.	Bale roof		Saddle / limasan roof	Triangular prism / quadrangular limas
4.	Pillar		Round support	Trapesium
5.	Granary		Curved-roof barn (lumbung-type)	Prism Triangle

4.3. Spatial-ethnomathematical reading of the Thai house

4.3.1. Inner layer: cosmology and worldview

The Inner layer of the Thai house is structured by a Theravada-inflected worldview in which a layered three-world cosmology informs the vertical articulation of the dwelling. The under-floor zone is associated with the ground and the realm of spirits and animals; the elevated living floor is the human zone; the upper roof is associated with the sacred and the ancestral. The riverine orientation – houses traditionally addressing the waterway as both a resource and a spiritual presence – adds a horizontal cosmological axis. Together, these orientations constitute a coordinate system in which the dwelling mediates vertical and horizontal cosmological relationships.

4.3.2. Middle layer: modular practice and the chan

The Middle layer of the Thai house is dominated by two interrelated practices: modular extension through the *hwang* bay system and social-climatic mediation through the *chan*. The Hwang functions as a proportional module that can be repeated to extend the dwelling, doubled at terminal elevations, or grouped into clusters connected by a shared veranda. The *chan* is described by Nivat and Prince (1955) as an essential as the sleeping quarters and the kitchen: a semi-outdoor space, typically elevated and without enclosing walls, that admits ample sunlight and air, supports communal use and family activity, and provides an unobstructed visual connection to the surroundings through semi-transparent balustrades. Prasertsuk (2015) frames this configuration as the architectural signature of Thai vernacular space – an environmentally responsive

integration of climatic device and social regulator. The Middle layer thus reveals the Thai house as a system of modular and mediating geometries enacted through use.

4.3.3. Outer layer: geometric form and proportion

The Outer layer expresses the Inner and Middle systems in geometrically explicit ways. Table 3 lists the basic geometric primitives identifiable in the Thai case, and Tables 4–5 enumerate the spatial volumes and the principal composed combinations that constitute its architectural signature.

Beyond primitives and combinations, the Thai case exhibits four spatial-mathematical signatures. First, the hwang bay system imposes a modular proportional discipline on the plan, with bay counts ranging from one to six or more. Second, the cluster arrangement composes single hwang units into U-shaped or rectangular groups around a central courtyard, producing a communal-space geometry that mediates collective life through the chan. Third, the stilted floor encodes a vertical three-zone subdivision that materialises the layered Theravada cosmology of the Inner layer. Fourth, roof pitch, eave projection, and gable terminations (ngao and panlom) follow proportional conventions that perform symbolic and climatic functions simultaneously.

4.4. Cross-cultural synthesis: cognate spatial-ethnomathematical systems

Reading the two cases through the IMO(E) framework reveals a set of cognate spatial-ethnomathematical operations across the Balinese and Thai houses. Both traditions impose a vertical cosmological hierarchy (Tri Angga in Bali; the three-world stilted articulation in Thailand). Both rely on modular subdivision of the plan (the 3×3 Sanga Mandala grid in Bali; the hwang module in Thailand). Both organize dwelling around an oriented axis (kaja–kelod in Bali; riverine orientation in Thailand). Both compose primitives – cube, triangular prism, cylinder – under a proportional discipline that is itself a function of cosmological scheme. The recognition of these cognate operations – rather than merely the inventory of shared primitives – is the principal analytical contribution of Section 3, and it provides the substantive ground for the (E)xperimental transformation developed in Section 4.

Table 3. Placement of 2D geometry in the Thai house typology (source: developed by author)

Shape	Visible parts	Notes
Square	Floor plan, floor of the house, central courtyard area	The base of the building module follows a symmetrical square.
Rectangle	Elongated building masses, terraces, and house platforms	Many traditional houses are elongated along a long axis.
Triangle	Side elevation of the gable roof	The roof comprises two opposing triangular planes.
Trapezium	Roof plane viewed in perspective	Visible when the roof is rendered three-dimensionally at an oblique angle.

Table 4. Placement of 3D geometry in the Thai house typology (source: developed by author)

Volume	Visible parts	Notes
Beam	Main building body; stilt legs	Elongated block volume.
Cube	Small rooms approximately equal in length and width	Service or auxiliary rooms.
Triangular prism	Gable roof (two-plane pitched roof)	An elongated triangular prism above the rectangular plan.
Quadrangular limas/ stomping limas	Roof variants with stepped or hipped tops	Adds visual articulation typical of vernacular form.
Cylinder	Multiple support posts	Round wooden columns common in stilted houses.

Table 5. Principal composed combinations in the Thai house typology (source: developed by author)

Composition	Location	Notes
Beam + triangular prism	Body + roof	The defining combination of Southeast-Asian vernacular dwelling.
Beam + limas	Buildings with taller, hierarchic roofs	Produces a spatial hierarchy in which the principal volume reads as elevated.
Curve/curve termination	Roof end (tail/horn)	An aesthetic-symbolic articulation marking cultural identity.

Table 6. Cross-cultural synthesis of spatial-ethnomathematical operations (source: developed by author)

Operation	Balinese expression	Thai expression
Cosmological hierarchy (vertical)	Tri Angga: head–body–foot tripartition of every element	Three-world stilted articulation: under-floor/ living floor/roof
Modular subdivision (planar)	Sanga Mandala: 3×3 grid across the karang	Hwang: one to six modular bays; doubled at terminal elevations
Orientation axis	Kaja–kelod axis toward Mount Agung; Nawa Sanga eight-direction scheme	Riverine orientation and prevailing-wind alignment
Communal-space geometry	Karang courtyard organised by Sanga Mandala zones	Central courtyard of grouped ruean mediated by the chan
Proportional discipline of primitives	Cube + triangular prism + cylinder under Tri Angga proportion	Beam + triangular prism + cylinder under hwang module

5. (E)xperimental transformation: from spatial-ethnomathematical analysis to contemporary design

The (E)xperimental layer of the IMO(E) framework translates the Inner–Middle–Outer findings of Section 3 into a contemporary residential design proposition. The objective is not to reproduce traditional form but to maintain the spatial-cosmological logic – proportion, modularity, orientation, and hierarchy – that gives traditional form its cultural value. Four transformation strategies derived from Antoniades et al. (1992) are deployed: abstraction, substitution, infill, and recombination. Each strategy is mapped to a specific spatial-ethnomathematical operation identified in the cross-cultural synthesis (Table 6).

5.1. Conceptual basis of the transformation

The initial concept of transformation applies the geometric character elements of Balinese and Thai traditional houses, using basic-form analysis grounded in spatial ethnomathematics. Sukada's account of typology – the tracing of the origin of architectural form – organizes the analysis in two preparatory steps: determining the formal structure of each architectural unit, and identifying its basic properties on the basis of constituent geometric primitives. Read through the IMO(E) framework, this typological reading constitutes the Outer layer, on which the Inner and Middle operations are then mapped, before transformation strategies are applied at the Experimental layer.

The transformation of the contemporary residential building was carried out to reinterpret the spatial character of the Balinese and Thai houses. A range of residential design samples was used as objects of study, with two-story buildings of innovative form selected because their building mass is sufficiently malleable to absorb the spatial-ethnomathematical operations being transferred. Since residential houses typically express their identity through the roof element, the roof becomes a principal site of transformation in the (E)xperimental phase. Several initial concepts were generated as sketches, refined into three-dimensional models, and iterated until the resulting from expressed the proportional discipline, modularity, hierarchy, and orientation of the source traditions without resorting to literal mimicry.

Visually, the resulting form should read as a distinct entity that still retains traces of identity and origin from both traditions, expressed through geometry, material, and the spatial logic of inhabitation. The cross-cultural analogy that orients the work is one of two design grammars yielding a third, in which the proportional system, modular logic, and orientation of both sources are recognisable in the contemporary outcome without the outcome being reducible to either.

5.2. Concept variants and selection

Three concept variants were tested. In Concept A, the modern building mass was "wrapped" in the Balinese roof typology; while the geometric primitives were retained, the contrast with the modern volume below was too sharp to permit a coherent translation of the proportional system. In Concept B, the inverse was attempted, applying the Thai house silhouette to a modern structure; similar limitations emerged, in which each tradition's spatial logic remained too autonomous to integrate. Concept C – the approach adopted in the final proposal – pursued proportional integration through infill, substitution, recombination, and abstraction, calibrated to the cross-cultural operations identified in Table 6. This integrative approach proved capable of carrying the modular, hierarchical, and orientational logics of both sources into a coherent contemporary residential form.

5.3. Application of transformation across residential elements

The transformation was applied to three principal architectural elements: the layout (plan), the structural articulation (including the stilted ground level), and the roof. Each element absorbed specific spatial-ethnomathematical operations from each source tradition (Table 7).

The transformation of the layout integrates two operations: the 3×3 hierarchic zoning of Sanga Mandala, recoded as a modular grid governing the plan, and the *Hwang* modular bay system, recoded as the proportional unit by

Table 7. Application of cubic/beam volumes to the contemporary residential layout (source: developed by author)

No	Balinese layout principle	Thai layout principle	Contemporary transformation
1.	Sanga Mandala: 3×3 zoning; hierarchic placement of pavilions around a courtyard	Hwang: modular bay system with grouped arrangement around a central court	Two-story layout: first-floor public–service zones, second-floor private zones, organized on a modular grid with a central interior court

which the grid is dimensioned (Figure 8). The stilted-floor system is retained as a contemporary raised ground level, and the spatial division between public, family, and private zones follows the Inner-layer hierarchy of both traditions while responding to the spatial needs and use patterns of a contemporary household (Figure 9). The second floor concentrates private zones; the first floor concentrates communal and service zones connected by a central interior space that abstracts the role of the *karang* courtyard and the *chan* veranda (Figure 10).

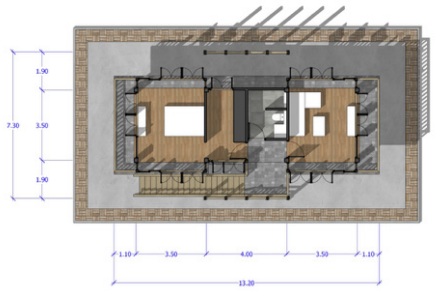

Figure 9. Contemporary residential first-floor plan (source: developed by author)

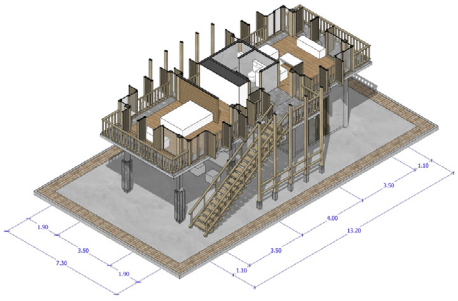

Figure 8. Contemporary residential second-floor plan (source: developed by author)

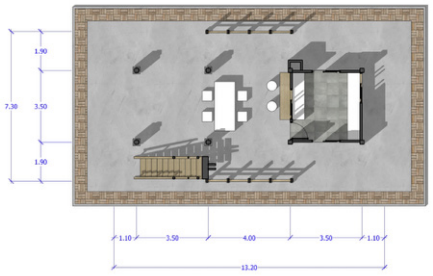

Figure 10. Axonometric view of the transformed contemporary residence (source: developed by author)

Table 8. Application of roof typologies in the contemporary residential design (source: developed by author)

No	Balinese roof principle	Thai roof principle	Contemporary transformation
1.	Tri Angga-proportioned saddle/ limasan roof; sacred terminations	Steep gable with long eaves; gable terminations (ngao, panlom); ventilated ridge	Roof Type 1: pitched roof with proportional head–body–foot articulation and ventilated ridge
2.	Limasan with multi-tier hierarchy	Stomping-limas with hierarchic stacking and overhanging eaves	Roof Type 2: stacked pitched roofs with deep overhangs over the principal volume; subordinate volumes carry abstracted gable terminations

The shape of the roof in the two source traditions encodes both proportional discipline and symbolic articulation. The transformation operates through abstraction of the proportional system (Tri Angga tripartition and Hwang-derived eave projection), substitution at the level of material (contemporary roofing membranes and structural systems replacing thatch and tile), and recombination of the gable termination motifs as a discrete head-of-roof articulation (Table 8). The result is a roof that performs climatically as in the source traditions – pitch for drainage, eaves for sun and rain protection, ventilated ridge for heat convection – while reading as contemporary rather than imitative (Figures 11–15).

Figure 11. Contemporary residence: principal facade (source: developed by author)

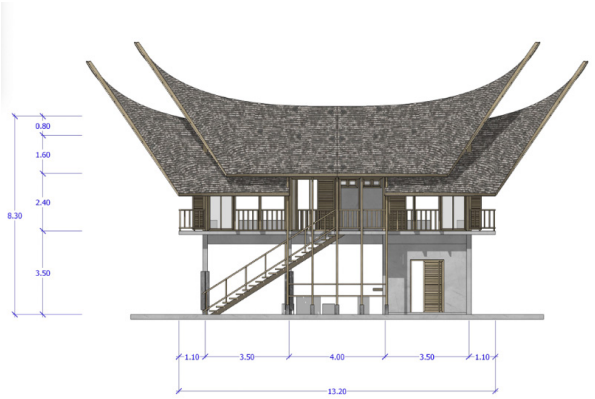

Figure 12. Contemporary residence: elevation study 1 (source: developed by author)

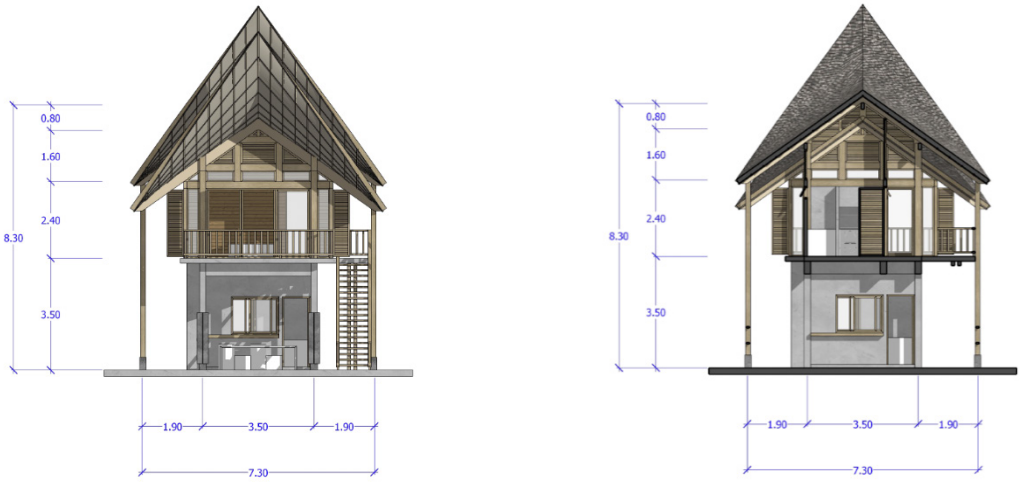

Figure 13. Contemporary residence: elevation study 2 (source: developed by author)

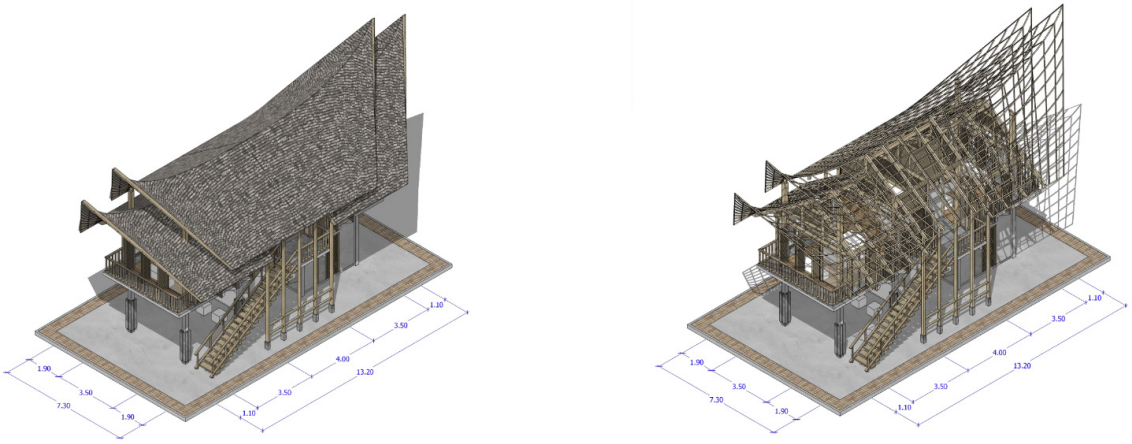

Figure 14. Contemporary residence: roof structure (source: developed by author)

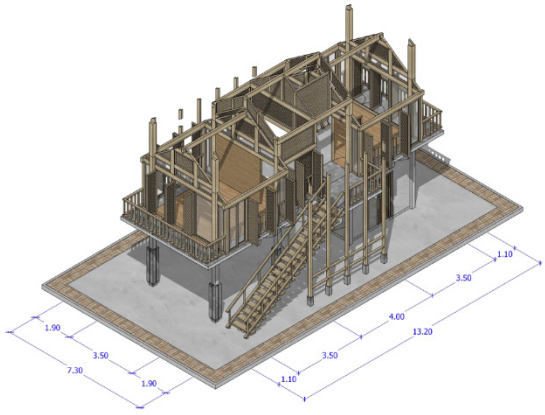

Figure 15. Contemporary residence: structural articulation (source: developed by author)

5.4. Discussion: maintaining cultural values through spatial-ethnomathematical translation

The transformation outcome demonstrates that the cultural values of the Balinese and Thai houses can be maintained in contemporary residential design through the spatial-ethnomathematical operations identified in Section 3, rather than through formal mimicry. The 3×3 hierarchic zoning derived from Sanga Mandala and the *hwang* modular bay are present in the contemporary plan as a modular hierarchic grid; the *kaja–kelod* and riverine orientation operations are abstracted into a primary entrance–courtyard–private axis; the *Tri Angga* vertical hierarchy and the three-world stilted articulation are abstracted into a raised ground level, principal living floor, and articulated roof; the gable termination of the Thai roof is recombined with the *limasan* articulation of the Balinese roof at the level of head-of-roof articulation.

Read against the three research questions of the Introduction, the transformation indicates: that the spatial-ethnomathematical systems of the two traditions exhibit cognate operations of hierarchy, modularity, orientation, and proportional discipline that can be articulated as a shared design vocabulary (RQ1); that the IMO(E) framework provides a workable protocol for translating Inner cosmology and Middle practice into Outer geometry in the Experimental phase (RQ2); and that abstraction, substitution, infill, and recombination, applied to each spatial-ethnomathematical operation rather than to surface form, allow contemporary residential design to maintain cultural values without literal replication (RQ3). The contemporary design proposal is therefore not a stylistic combination of two traditions but a spatial-ethnomathematical synthesis in which their cultural values are sustained as living design knowledge (Table 9).

Table 9. Element-by-element mapping of source operations to the contemporary residence (source: developed by author)

Residential element	Balinese transformation	Thai transformation
Layout	Sanga Mandala 3×3 hierarchic zoning → modular grid	—
Building structure	Tri Angga vertical tripartition	Hwang modular bay + stilted ground level
Roof	Tri Angga-proportioned roof typology	Gable/stomping-limas with eave projection

6. Conclusions

This study has investigated how the cultural values of Balinese and Thai traditional houses can be maintained in contemporary residential design through the lens of spatial ethnomathematics, operationalized within the IMO(E) framework. The principal argument is that cultural values are sustained not by replicating traditional form but by maintaining the spatial-cosmological logic – proportion, modularity, orientation, and spatial hierarchy – that the form materializes. The Balinese *karang* and the Thai *ruean* were read as cognate spatial-ethnomathematical systems whose Inner cosmologies, Middle practices, and Outer geometries can be cross-mapped and recombined.

Three principal findings emerge. First, the two traditions exhibit cognate mathematical-cultural operations: a vertical cosmological hierarchy (*Tri Angga* in Bali; three-world stilted articulation in Thailand); a modular planar subdivision (*Sanga Mandala* in Bali; *hwang* in Thailand); an orientation axis (*kaja–kelod* in Bali; riverine and wind-aligned in Thailand); a communal-space geometry (*karang* courtyard; chan-mediated central courtyard); and a proportional discipline of basic primitives. Second, the IMO(E) framework provides an effective protocol for moving from this stratified analysis to contemporary design, because the Experimental layer is the operational site where abstraction, substitution, infill, and recombination strategies can be applied systematically to each Inner–Middle–Outer operation. Third, the transformation strategies, when applied to spatial-ethnomathematical operations rather than to surface forms, yield a contemporary residential design that maintains cultural identity, climatic responsiveness, spatial coherence, and cultural continuity, without descending into literal replication or stylistic eclecticism.

The implications for design practice and culture-based design education are threefold. For designers and architects, the IMO(E)-driven spatial-ethnomathematical reading offers a transferable protocol for engaging vernacular sources beyond the level of motif. For educators, the framework provides a stratified pedagogy in which students can be guided to recognise the cultural-mathematical structures of vernacular form before being asked to redeploy them. For cultural actors and policymakers concerned with the maintenance of cultural identity in the face of rapid urban modernization, the study offers an alternative to a purely preservationist disposition: cultural values can be carried forward through living design practice when

the underlying spatial-ethnomathematical logic is made the object of transmission.

The study has limitations that orient subsequent work. The analysis is restricted to two cases and to one contemporary residential typology; broader cross-cultural extension across additional Southeast Asian vernacular systems, as well as application to non-residential typologies, would test the generality of the operations identified here. Spatial-ethnomathematical analysis would also benefit from systematic field measurement of proportional ratios and modular dimensions, complementing the typological-morphological reading developed in this study. Future work should therefore (i) extend the comparative cross-cultural set, (ii) integrate field-measured proportional data into the Outer-layer analysis, and (iii) test the (E)xperimental transformation protocol across a wider range of contemporary typologies, including multi-unit and public-programme buildings.

Within the boundaries of the present study, spatial ethnomathematics – operationalized through the IMO(E) framework – demonstrates its capacity to function as a methodological bridge between vernacular cultural knowledge and contemporary design practice, and so as a vehicle for maintaining the cultural values of the Balinese and Thai traditional house.

Acknowledgements

We would like to thank Maranatha Christian University for the Support Grant and Silpakorn University, Bangkok, for the Doctoral Program in Design Arts (International Program).

Author contributions

Erwin Ardianto Halim – Served as the lead author; conceptualized the study; designed the research framework; conducted initial surveys; developed the preliminary analysis; and contributed substantially to writing, revising, and finalizing the manuscript. Eakachat Joneurairatana – Acted as academic advisor; provided theoretical guidance; supervised methodological development; refined the analytical approach; and contributed to critical review and substantive academic revisions. Visuwat Malai – Produced all modern-house visualizations; developed architectural illustrations and comparative design diagrams; assisted in interpreting spatial characteristics; and contributed to the visual communication components of the manuscript. Klawkanlayaphon Sawatmongkhonkul – Conducted fieldwork and data collection on traditional Thai houses; documented architectural typologies and spatial arrangements; and provided contextual insights for cross-cultural comparison. Yudita Royandi – Processed and analyzed data related to traditional Indonesian houses; organized ethnographic and architectural datasets; contributed to coding, categorization, and interpretation of Indonesian spatial attributes. Shirly Nathania Suhanjoyo – Supported data processing for Indonesian traditional houses; assisted in visual–spatial mapping and pattern identification; and contributed to drafting descriptive sections related to Indonesian cultural architecture.

Disclosure statement

The authors declare that they have no relevant financial interests that relate to the subject of this paper.

References

Adam, S. (2004). Ethnomathematical ideas in the curriculum. *Mathematics Education Research Journal*, *16*, 49–68. https://doi.org/10.1007/BF03217395

Adnyana, I. B. M. A. Y., Kardinal, N. G. D. A., & Sudharsana, I. M. G. (2021). Komparasi Permukiman Desa Adat Tenganan Pegringsingan dengan Desa Adat Tenganan Dauh Tukad di Karangasem Bali [Comparison of the settlements of Tenganan Pegringsingan tarditional village in Karangasem Bali]. *Pranatacara Bhumandala*, *2*(1), 49–64. https://doi.org/10.32795/pranatacara_bhumandala.v2i1.1724

Albanese, V., & Perales, F. J. (2014). Pensar matemáticamente: una visión etnomatemática de la práctica artesanal soguera [Thinking mathematically: An ethnomathematical vision of the artisanal practice of Soguera]. *Revista Latinoamericana de Investigación en Matemática Educativa*, *17*(3), 261–288. https://doi.org/10.12802/relime.13.1731

Antoniades, H. N., Neville-Golden, J., Galanopoulos, T., Kradin, R. L., Valente, A. J., & Graves, D. T. (1992). Expression of monocyte chemoattractant protein 1 mRNA in human idiopathic pulmonary fibrosis. *Proceedings of the National Academy of Sciences*, *89*(12), 5371–5375. https://doi.org/10.1073/pnas.89.12.5371

Ardiana, P. A., Sujana, I. K., Natalia, S. A. P. D., & Yanthi, K. D. L. (2026). Tri Hita Karana: Balinese local wisdom and its role in the triumph over corruption. *Journal of Accounting & Organizational Change*, *22*(1), 127–148. https://doi.org/10.1108/JAOC-11-2023-0182

Arunoprayote, S. (2022). A study of the physical characteristics of Chinese cemetery landscapes in Inner Bangkok. *Sarasatr: Journal of Architecture and Design*, *5*(2), 233–247.

Aryani, N. P., & Tanuwidjaja, G. (2013). Sustainable architectural design in a traditional Balinese housing in accordance to the concept of Tri Mandala. *Journal of Architecture&ENVIRONMENT*, *12*(2), 113–124. https://doi.org/10.12962/j2355262x.v12i2.a561

Ascher, M. (1991). *Ethnomathematics: A multicultural view of mathematical ideas* (1st ed.). Routledge. https://doi.org/10.1201/9780203756522

Birdwell-Pheasant, D., & Lawrence-Züniga, D. (1999). *House life: space, place and family in Europe* (1st ed.). Routledge. https://doi.org/10.4324/9781003103240

Bishop, A. (1991). *Mathematical enculturation: A cultural perspective on mathematics education* (Vol. 6). Springer. https://doi.org/10.1007/978-94-009-2657-8_6

Chiranthanut, C. (2020). Inherent wisdoms and the roles of sacred spaces in spatial organization of vernacular houses. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *44*, 19–23. https://doi.org/10.5194/isprs-archives-XLIV-M-1-2020-19-2020

Chuapram, S., King, R., & Panin, O. (2012). Transformation of local living: Buddhist Thai communities and vernacular houses around Songkhla Lake basin. *Procedia-Social and Behavioral Sciences*, *50*, 42–54. https://doi.org/10.1016/j.sbspro.2012.08.014

D'Ambrosio, U. (1985). Ethnomathematics and its place in the history and pedagogy of mathematics. *For the learning of Mathematics*, *5*(1), 44–48.

D'Ambrosio, U. (2006). *Ethnomathematics*: *Link between traditions and modernity*. Brill. https://doi.org/10.1163/9789460911415

Dwijendra, N. K. A. (2008). *Arsitektur rumah tradisional Bali*: *berdasarkan asta kosala-kosali*. *Kerjasama Bali Media Adhikarsa* [*dengan*] [Traditional Balinese house architecture. A collaboration with Bali media adhikarsa [with]]. Udayana University Press.

Eglash, R. (1999). *African fractals*: *Modern computing and indigenous design*. Rutgers University Press.

Ferschin, P., Di Angelo, M., & Paskaleva, G. (2013 October 28–November 1). Parametric Balinese rumah: Procedural modeling of traditional Balinese architecture. In *2013 Digital Heritage International Congress* (*DigitalHeritage*), (pp. 199–206). Marseille, France. IEEE. https://doi.org/10.1109/DigitalHeritage.2013.6744755

Frampton, K., Frampton, K., Frampton, K., & Frampton, K. (1980). *Modern architecture*: *A critical history* (Vol. 4). Thames and Hudson.

Gherardi, S. (2000). Practice-based theorizing on learning and knowing in organizations. *Organization*, *7*(2), 211–223. https://doi.org/10.1177/135050840072001

Glassie, H., & Truesdell, B. (2008). A life in the field: Henry Glassie and the study of material culture. *The Public Historian*, *30*(4), 59–87. https://doi.org/10.1525/tph.2008.30.4.59

Gelebet, I. N., & Puja, I. G. N. A. (2002). *Arsitektur tradisional daerah Bali* [Traditional Architecture of Bali]. Bagian Proyek Pengkajian dan Pemanfaatan Sejarah dan Tradisi Bali.

Halim, E. A. (2016). Studi Perilaku Adaptasi Manusia terhadap Lingkungan Sosial dalam Penambahan Fungsi Ruang Komersial Hunian Tradisional Bali di Ubud [A study of human adaptation behavior to the social environment in the addition of the function of commercial space of traditional Balinese housing in Ubud]. *Serat Rupa*: *Journal of Design*, *1*(2), 389–405. https://doi.org/10.28932/srjd.v1i2.460

Halim, E. A., & Joneurairatana, E. (2024). *Transforming of the Sumba pattern into light*, *shadow*, *and shade for contemporary lamp design* [Doctoral dissertation, Silpakorn University].

Halim, E. A., Joneurairatana, E., Vongphantuset, J., & Jamuni, P. (2023). "Mamuli" pattern in East Sumba woven fabric as inspiration for "Kandunnu" standing lamp using the IMOE method. *ISVS Ejournal*, *7*(3), 1–13.

He, M., & Qi, J. (2019). Study on the theory of Rafael Moneo architectural typology. *IOP Conference Series*: *Materials Science and Engineering*, *592*, Article 012105. https://doi.org/10.1088/1757-899X/592/1/012105

Joneurairatana, E. (2021). *Art and design research* [Doctoral dissertation, Silpakorn University].

Kumurur, V. A., & Damayanti, S. (2009). Pola perumahan dan pemukiman Desa Tenganan Bali [Housing and Settlement Patterns in Tenganan Village, Bali]. *Jurnal Sabua*, *1*(1), 1–7.

Leong, B. D., & Clark, H. (2003). Culture-based knowledge towards new design thinking and practice: A dialogue. *Design Issues*, *19*(3), 48–58. https://doi.org/10.1162/074793603768290838

Massarwe, K., Verner, I., Bshouty, D., & Verner, I. (2010). An ethnomathematics exercise in analyzing and constructing ornaments in a geometry class. *Journal of Mathematics and Culture*, *5*(1), 1–20.

Mildawani, I., Asmiwyati, I. G. A. A. R., Apriyanti, R., Prabawasari, V. W., & Akhirson, A. (2024). The application of Tri Hita Karana principles in landscape architecture and urban planning: A case study of Kedonganan Traditional Village, Bali. *Evolutionary Studies in Imaginative Culture*, *8*(2), 869–878. https://doi.org/10.70082/esiculture.vi.741

Ministry of Tourism, Republic of Indonesia. (2026). *Traditional houses in Bali*. https://www.indonesia.travel/gb/en/travel-ideas/culture/traditional-houses-in-bali

Nivat, D., & Prince, H. (1955). The reconstruction of Rama I of the Chakri dynasty. *Journal of the Siam Society*, *43*(1), 262–265.

Nurmala, C. W., Asrofi, M. H., Maqsuna, A. R., Madikha, A., Paramitha, S. A., Fatoni, F., & Virgiawan, D. B. (2025). Implementation of zoning theory based on the concept of Tri Hita Karana, Tri Mandala and Sanga Mandala of Mas Village, Ubud, Bali in Maintaining cultural values. *Sustainability* (*STPP*) *Theory*, *Practice and Policy*, *5*(1), 59–73. https://doi.org/10.30631/sdgs.v5i1.3176

Oliver, P. (2006). *Built to meet needs*: *Cultural issues in vernacular architecture* (1st ed.). Routledge. https://doi.org/10.4324/9780080476308

Parwata, I. W. (2011). Rumah Tinggal Tradisional Bali dari Aspek Budaya dan Antropometri [Balinese traditional residence from cultural and anthropometric aspects]. *Mudra Jurnal Seni Budaya*, *26*(1), 95–106. https://doi.org/10.31091/mudra.v26i1.1593

Peters, J. H. (2013). *Tri Hita Karana*. Kepustakaan Populer Gramedia.

Pintong, S. (2017). *Revitalizing the fundamental elements of Thai House* [Doctoral thesis, Silpakorn University]. http://ithesis-ir.su.ac.th/dspace/handle/123456789/684

Pradnyasari, N. K. I. (2017). The '*Tri Mandala*' *concept in the outdoor spatial layout of Badung Traditional Market*, *Denpasar City* [Doctoral thesis, Universitas Brawijaya].

Prahmana, R. C. I. (2022). Ethno-realistic mathematics education: The promising learning approach in the city of culture. *SN Social Sciences*, *2*(12), 257. https://doi.org/10.1007/s43545-022-00571-w

Prasertsuk, S. (2015). Architectural composition for utilities and spatial connection in modern Thai architecture. *Journal of Architectural/Planning Research and Studies* (*JARS*), *2*, Article 257.

Rapoport, R., & Rapoport, R. N. (1969). The dual career family: A variant pattern and social change. *Human Relations*, *22*(1), 3–30. https://doi.org/10.1177/001872676902200101

Riyanto, E. D., & Bhattacarya, W. (2022). Tri Mandala: Kearifan Lokal Bali dalam Pembagian Zonasi dan Ruang pada Bangunan Pura di Kabupaten Sidoarjo [Tri Mandala: Balinese local wisdom in the distribution of zoning and space in temple buildings in Sidoarjo Regency]. *Sphatika*: *Jurnal Teologi*, *13*(1), 108–119. https://doi.org/10.25078/sphatika.v13i1.1272

Roth, D., & Sedana, G. (2015). Reframing Tri Hita Karana: From 'Balinese culture' to politics. *The Asia Pacific Journal of Anthropology*, *16*(2), 157–175. https://doi.org/10.1080/14442213.2014.994674

Samadhi, T. N. (2004). Making cosmo-religious landscapes: The design of a Balinese town's civic center (Bali, Indonesia). *Habitat International*, *28*(1), 103–122. https://doi.org/10.1016/S0197-3975(03)00032-8

Sathāpitānon, N., & Mertens, B. (2012). *Architecture of Thailand*: *A guide to tradition and contemporary forms*. Editions Didier Millet.

Solihin, S., & Sumawidari, I. A. K. (2021). Tri hita karana implementation in accommodation management (the case of traditional balinese homestays in Ubud). *International Journal of Glocal Tourism*, *2*(3), 146–159. https://doi.org/10.58982/injogt.v2i3.70

Sulistyawati, I., Nugoho, N., Suryokusumo, S., & Hadi, Y. S. (2008). Maximum stiffness and flexural strength of glulam and solid acacia wood beams. *Jurnal Teknik Sipil ITB*, *15*(3), 113–122. https://doi.org/10.5614/jts.2008.15.3.3

Suryada, I., & Bagus, G. A. (2012). The concepts of Tri Mandala and Sanga Mandala in traditional Balinese architectural layout. *Jurnal SUlapa*, *4*(1), 23–32.

Taş, E., & Özcan, U. (2023). Sustainable architecture applications based on culture and religion In Bali traditional architecture. *International Journal of Social And Humanities Sciences*, *7*(3), 11–36.

Tengkaoprasert, R. (2018). The concept of energy conservation in architectural design and the creation of modern Thai architectural identity. *Athens Journal of Architecture*, *4*(2), 171–190. https://doi.org/10.30958/aja.4-2-2

Throsby, D. (1999). Cultural capital. *Journal of Cultural Economics*, *23*(1), 3–12. https://doi.org/10.1023/A:1007543313370

Wastika, D. N. (2005). Application of the Tri Hita Karana concept in housing planning in Bali. *Jurnal Permukiman Natah*, *3*(2), 62–105.

Wolfrum, S., & Janson, A. (2019). *The city as architecture*. Birkhäuser. https://doi.org/10.1515/9783035618051