

Vernacular Architecture and Indoor Environmental Satisfaction: A Systematic Review of Influencing Factors

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Abstract

This systematic literature review investigates the factors influencing indoor environmental satisfaction in vernacular architecture, with particular attention to sustainability and sociocultural contexts. Drawing on 105 peer-reviewed studies published over the past two decades, the analysis employed thematic synthesis and cluster analysis to identify key design features, theoretical underpinnings, and variables affecting occupant satisfaction. Five major theories emerged, with Sustainability Theory, Bioclimatic Architecture Theory, and Ecological Systems Theory most frequently applied. Cluster analysis of 62 variables produced eight thematic categories, offering a structured basis for hypothesis development and integrative model formulation. The review further identified critical research gaps, including limited empirical validation, methodological inconsistencies, and underutilization of theory in explaining outcomes. Findings reveal that vernacular design features such as courtyards, shading devices, and materiality strongly contribute to SIEQ, while contemporary transitions risk diminishing comfort. This review highlights critical research gaps, particularly evaluation voids and theoretical underuse, and proposes integrative directions for architects and policymakers.

Keywords: vernacular architecture; indoor environmental satisfaction; sustainability theory; occupant well-being



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1. Introduction

Climate change, rapid urbanization, and rising energy demand have intensified global concerns regarding the sustainability and resilience of the built environment. In this context, vernacular residential architecture (VRA) offers critical lessons, reflecting generations of adaptation to local climates, materials, and cultural practices. In warm-humid regions such as coastal Karnataka, India, vernacular houses exemplify climate-responsive strategies ranging from courtyards and cross-ventilation to shaded verandahs and locally sourced materials that align closely with contemporary sustainability objectives. Yet, the transition from vernacular to modern construction has often disrupted this balance, compromising both environmental responsiveness and occupant satisfaction with indoor environmental quality (SIEQ). Understanding how VRA contributes to SIEQ is therefore essential for advancing scholarships and guiding sustainable design practices.

Globally, VRA has attracted increasing attention for its climate-responsive design principles and its potential to enhance environmental sustainability [1]. As cities expand and energy demand rises, integrating vernacular strategies into modern contexts is becoming increasingly relevant. This review, therefore, examines how vernacular design features

influence satisfaction with indoor environmental quality (SIEQ), a user-centered construct encompassing thermal comfort, indoor air quality, lighting, and acoustics [2–5].

Existing research demonstrates that local materials, traditional construction practices, and culturally grounded design considerations can significantly improve SIEQ [1]. However, while individual aspects of these relationships have been investigated, few studies have adopted an integrated framework to examine how VRA design features collectively shape SIEQ [6,7]. To address this, the present review draws on five theoretical perspectives—Sustainability Theory, Bioclimatic Architecture Theory, Ecological Systems Theory, Social Cognitive Theory, and the Theory of Planned Behavior [8–12]. Together, these frameworks provide a multidimensional lens for understanding the environmental, cultural, and behavioral factors influencing SIEQ.

Despite these advances, the specific factors and variables underpinning SIEQ in vernacular houses have not been systematically synthesized. Research gaps remain in developing holistic models applicable to contemporary urban contexts. This study addresses these gaps through a systematic literature review (SLR) of 105 peer-reviewed publications spanning seven decades. The review identifies and analyzes the antecedents of SIEQ in vernacular houses, synthesizes theoretical frameworks, and maps design features that can guide sustainable, culturally grounded building practices.

Accordingly, the study is guided by four research questions: (i) Which theoretical frameworks are most frequently applied to explore VRA and SIEQ? (ii) How are research focuses and types distributed across the literature? (iii) How can variables be clustered to conceptualize antecedents of SIEQ? (iv) What research gaps remain, and how can these inform future inquiry?

2. Materials and Methods

This research adopts an evidence-based systematic literature review (SLR) approach to consolidate knowledge on vernacular residential architecture (VRA) and satisfaction with indoor environmental quality (SIEQ). An SLR is a replicable and transparent process that minimizes bias through exhaustive searches, unlike traditional narrative reviews, and has been shown to identify areas requiring clarity and highlight topics warranting further investigation [13]. While the method has long been established in medicine and healthcare, it has gained increasing attention in fields such as software engineering, environmental sciences, and management. Although numerous narrative reviews exist on various aspects of VRA, few SLR studies have been conducted in the specific context of VRA and SIEQ. This study seeks to address that gap by systematically synthesizing evidence across seven decades of research.

The review followed the SALSA framework (Search, Appraisal, Synthesis, and Analysis) and complied with the PRISMA 2020 guidelines [14], ensuring methodological transparency and replicability. To improve clarity, the methodology is organized sequentially into four stages: Planning, Selection, Extraction, and Execution.

2.1. Research Design and Contributions

The review was designed to consolidate theoretical perspectives, cluster variables, and identify gaps in VRA–SIEQ research. Database searches, screening, and coding were independently performed by the author, with iterative validation by the co-author to minimize bias. Original contributions of this study include:

1. Mapping applications of five theoretical frameworks (SUT, BAT, EST, SCT, TPB).
2. Classifying 105 studies across research focus, research type, and contribution type.
3. Identifying 62 variables and clustering them into eight themes.
4. Developing an integrative model linking theories, clusters, and research gaps.

2.2. SALSA Framework and PRISMA Guidelines

The SALSA framework provided the overarching structure:

- Search: Comprehensive retrieval of literature across databases.
- Appraisal: Screening of studies for relevance and quality.
- Synthesis: Categorization of variables, theories, and contributions.
- Analysis: Identification of thematic clusters, gaps, and implications.

The PRISMA 2020 guidelines [14] were applied to ensure rigorous reporting of inclusion/exclusion criteria and the screening process.

2.3. SLR Stages

2.3.1. Planning

Database searches were conducted in Scopus, Web of Science, ProQuest, and Google Scholar, restricted to title, abstract, and keywords. Quotation marks were applied selectively to avoid overly restrictive results. Duplicates were removed using EndNote 21 (Clarivate, Version 21.3, released 2024, <https://endnote.com/>) and manual verification. Bibliometric cluster analysis was conducted in VOSviewer (Version 1.6.20, <https://www.vosviewer.com/>), and extracted variables were coded and organized in Microsoft Excel (Office 365, Version 2023). The PRISMA 2020 flow diagram was prepared using the official PRISMA flow diagram generator (<http://www.prisma-statement.org/>). This process is detailed in Table 1 and illustrated in the PRISMA flow diagram (Figure 1).

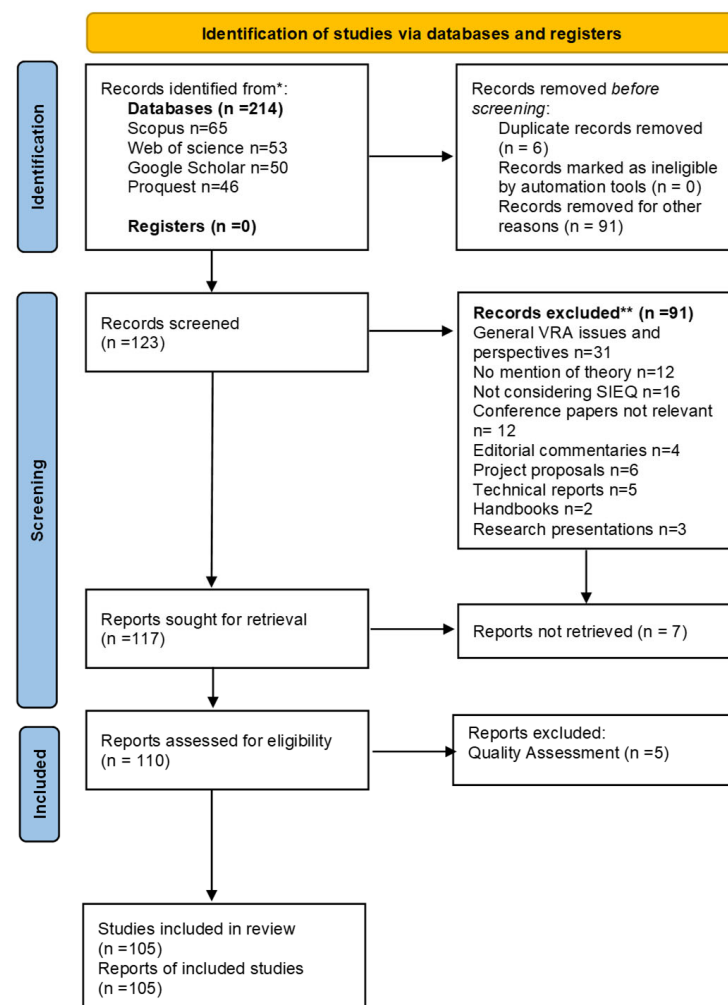


Figure 1. PRISMA 2020 flow diagram of the study selection process.

Table 1. Search strings and Boolean operators.

Theory/Concept	Key Words and Strings with Boolean Operators
1. Sustainability Theory	("Sustainable Development" OR "Sustainability Theory" OR "Sustainable Architecture" OR "SUT") AND ("Indoor Environmental Quality" OR "Satisfaction with Indoor Environment" OR "SIEQ") AND ("Vernacular Architecture" OR "Traditional Architecture" OR "Indigenous Architecture")
2. Bioclimatic Architecture Theory	("Bioclimatic Architecture" OR "Bioclimatic Design" OR "BAT") AND ("Indoor Environmental Quality" OR "Satisfaction with Indoor Environment" OR "SIEQ") AND ("Vernacular Architecture" OR "Traditional Architecture" OR "Indigenous Architecture")
3. Ecological Systems Theory	("Ecological Systems Theory" OR "EST") AND ("Indoor Environmental Quality" OR "Satisfaction with Indoor Environment" OR "SIEQ") AND ("Vernacular Architecture" OR "Traditional Architecture" OR "Indigenous Architecture")
4. Social Cognitive Theory	("Social Cognitive Theory" OR "SCT") AND ("Indoor Environmental Quality" OR "Satisfaction with Indoor Environment" OR "SIEQ") AND ("Vernacular Architecture" OR "Traditional Architecture" OR "Indigenous Architecture")
5. Theory of Planned Behavior	("Theory of Planned Behavior" OR "TPB") AND ("Indoor Environmental Quality" OR "Satisfaction with Indoor Environment" OR "SIEQ") AND ("Vernacular Architecture" OR "Traditional Architecture" OR "Indigenous Architecture")

2.3.2. Selection

Literature was retrieved from Scopus, Web of Science, ProQuest, and Google Scholar, in line with established SLR protocols. Inclusion criteria restricted studies to peer-reviewed journal articles and conference papers in English addressing VRA and environmental/occupant outcomes. Exclusion criteria removed duplicates, non-English works, Gray literature, and irrelevant studies. Screening was conducted in two stages: title/abstract review and full-text review.

Research articles from the past 20 years were considered in this SLR to ensure coverage of recent literature while capturing the gradual developments in model building, testing, and advancements in vernacular architecture (VRA). This timeframe is deemed appropriate given the ongoing evolution of both satisfaction with indoor environmental quality (SIEQ) and VRA. Over the past two decades, significant progress has been made in architectural theory and environmental design, particularly with respect to sustainability, climate-responsive design, and the application of theories such as the Theory of Planned Behaviour (TPB) and Ecological Systems Theory (EST) [8,15]. Furthermore, the growing use of computational modelling in recent years aligns with the focus of this study and is well represented within this time span [16]. Thus, selecting this period ensures that the theoretical contributions and conclusions of the reviewed articles align with the objectives of this research.

Inclusion Criteria

The articles were included if they:

- Time Frame: Studies that were published between 2004 and 2024, to include recent and pertinent studies, and at the same time, have a broad coverage on various aspects of VRA.
- Language: To ensure consistency in interpretation and understanding, the publication language is restricted to English only.
- Focus Area: Research dealing with the impact on the indoor environment through VRA. Studies that consider any of the five prominent theories: Social Cognitive Theory, Ecological Systems Theory, Bioclimatic Architecture Theory, Sustainability Theory, and Theory of Planned Behavior in the context of VRA.

- Research Type: Research approaches—qualitative, quantitative, and mixed methods. Theoretical papers, systematic reviews, and meta-analyses provide substantial insights into the relationship between VRA and SIEQ. Studies conducted in similar coastal climatic conditions as in India, characterized by warm and humid climates.
- Publication Type: Peer-reviewed journal articles, conference papers, and books that are recognized in the field of architecture, social sciences, and environmental studies.

Exclusion Criteria

Research articles were excluded if they:

- Time Frame: Studies were published before 2004.
- Language: Studies published in languages other than English.
- Focus Area: Research that does not address VRA or Indoor Environmental Quality, Studies that do not engage with the theories considered in this research, Papers focused on modern architectural practices without connection to VRA design principles.
- Research Type: Opinion pieces, non-peer-reviewed articles, and editorials, Studies that lack methodological rigor and cannot be classified as literature review, model development, model testing, model advancement, or model integration.
- Publication Type: Theses, dissertations, and unpublished work, unless they are very relevant to VRA and SIEQ and are peer-reviewed or published in recognized academic outlets.

Quality Assessment

To ensure methodological rigor, a quality assessment of the selected papers was undertaken. Criteria included clarity of findings and conclusions, robustness of data analysis, methodological rigor, and relevance to the study themes. Most publications were sourced from reputable databases indexed in SCOPUS and Web of Science (WOS), and the majority had an impact factor of 2.5 or higher, reinforcing their scholarly caliber. This assessment ensured that only high-quality, pertinent studies were included, thereby strengthening the validity of the SLR and providing a robust foundation for developing the conceptual model and identifying research gaps.

Following this process, data extraction and synthesis were undertaken in subsequent stages.

2.3.3. Extraction

A total of 214 published papers were initially retrieved using the defined search terms. Following the PRISMA guidelines [14], these records were systematically screened and assessed for relevance and quality. Through a four-stage elimination process, the final dataset was reduced to 105 peer-reviewed publications spanning seven decades, as illustrated in Figure 1. Data extraction was carried out using a structured coding sheet and organized into three components:

- General characteristics of the papers—including geographical distribution, database sources, indexing bodies, and methodological approaches, along with bibliographic details (author, title, year).
- Classification schemes—grouping studies by contribution to theory, research focus, and research type.
- Identification of variables—extracting influential factors related to satisfaction with indoor environmental quality (SIEQ) in vernacular houses, documented systematically in Microsoft Excel for consistency and traceability.

2.3.4. Execution (Synthesis and Analysis)

The final stage of the SLR involved synthesizing and analysing the extracted data through three complementary steps:

Classification Scheme

The 105 studies were systematically mapped using three schemes:

- Contribution to theory allocation to one or more of the five theoretical frameworks (SUT, BAT, EST, SCT, TPB).
- Research focus—grouped into four categories: model development, model testing, model advancement, and model integration.
- Research type—categorized into grounded theory, descriptive study, case study, document analysis, empirical research, and analytical research. This classification provided the foundation for structured synthesis across the reviewed literature.

Theoretical Mapping

Applications of the five theoretical frameworks were systematically documented, enabling comparative analysis of how each has been applied in the context of VRA and SIEQ.

Cluster Analysis

The classification process provided a structured basis for analyzing research contributions. The results are presented in Table 2, which summarizes the 105 reviewed studies by research focus, type, and contribution. Sixty-two variables cited across the reviewed studies were then consolidated into eight thematic clusters. A multi-stage cluster analysis, using a single-linkage approach, grouped variables under shared operational definitions, thereby providing a coherent framework for understanding antecedents of SIEQ. These classifications also informed the subsequent analysis of theoretical applications and variable clustering, forming the basis for Section 4.

Table 2. Data Extraction.

Author and Reference	Type of Research	Objectives	Research Approach	Key Findings	Key Factors in the Study	Review Remarks	Research Gap
Chandel et al. (2016) [1]	Model Advancement	To study indoor thermal comfort through energy-efficient vernacular architecture features for adaptation in modern architecture.	Qualitative	The study provides adaptation strategies for modern architecture, particularly in the Himalayan region through vernacular architecture features that contribute to thermal comfort.	Building materials, Roof materials, Thermal comfort Orientation, Space planning, Openings, Sunspace provision, Construction techniques.	The study provides insights for sustainable building practices through a comprehensive review of vernacular architecture features and their applicability in modern contexts. offering.	Evaluation void: Further evaluation of the effectiveness of these features in modern contexts is necessary.
Al-Obaidi, Woods, & Hassan (2017) [15]	Model Development	Green stormwater infrastructure model development of public spaces.	Qualitative	Three Gray space models (models for transitional zones) based on green stormwater. infrastructure: separation-association, half-association, and complete association, was validated through a case study.	Green stormwater infrastructure, Sustainable Design, Environmental Sustainability, Space Planning, Resource Management, Gray space, Traditional architecture, Stormwater utilization.	This research integrated architectural ecology with green stormwater infrastructure and provided innovative models for urban public spaces.	Methodological conflict: Methodological refinement and testing in diverse urban contexts is required.
Bourdeau, Pirard, & Dupont (2022) [16]	Model Development	To provide machine-learning-based real-time prediction scheme (ML-PIS) for evaluation of indoor humidity status in unlabelled positions within buildings.	Quantitative	Traditional spatial interpolation algorithms have been outperformed by ML-PIS significantly in reducing errors and predicting indoor humidity at unlabelled positions.	Spatial graph model, Indoor environmental quality, Humidity, Machine learning, Real-time prediction.	It is a novel approach to improving real-time indoor environment monitoring, with significant implications for digital buildings.	Evaluation void: Further evaluation is needed across different environmental variables and building types is required.
Berardi, 2020 [17]	Model Development	To enhance indoor air quality and thermal comfort by analyse the impact of energy-efficient ventilation strategies in vernacular architecture.	Quantitative	The cross ventilation and operable windows, significantly reduce indoor CO ₂ levels and improve thermal comfort.	Thermal comfort, Carbon-dioxide levels, Cross ventilation, Operable windows, Ventilation rate,	Useful insights into the passive cooling strategies of vernacular buildings are provided.	Evaluation void: Evaluation of the suggested strategies across different climate zones and building types are required to generalize the findings.
Singh et al. (2024) [18]	Model Development	To study the influence of locally sourced materials in in tropical climates in achieving thermal comfort and energy efficiency in vernacular buildings.	Qualitative	Bamboo and laterite stone have merged out to be effective in providing thermal insulation and humidity control in tropical regions.	Thermal insulation, Humidity control, locally sourced wood, Laterite stone usage, Adaptive clothing.	The research provides valuable insights into the role of materials in passive cooling.	Knowledge void: The long-term performance of these materials in urban construction must be explored.
Aelenei, Aelenei, & Gonçalves (2023) [19]	Model Integration	To develop an integrated approach for structural and thermal retrofitting strategies for masonry wall.	Qualitative	Structural retrofitting is necessary in high seismic risk areas, and the best solution is location dependent.	Thermal comfort, Ecological cost, Seismic capacity, Environment quality.	The integrated approach considering both structural and thermal aspects has been achieved.	Methodological conflict: Methods refinement is required as results are not corroborated well with earlier studies.
Attia, Gratia, De Herde, & Hensen (2020) [20]	Model Advancement	To identify similarities, differences, and limitations of building component rating models.	Qualitative	The objectives, scope, and aggregation techniques differed in the rating systems, but similarities were observed in methodology, and, processes were highly subjective.	Environmental quality, building component rating systems, Building performance, Condition assessment, Rating scale, Weighting coefficients.	The comparison of building component rating models, of this study are useful in highlighting key areas for improvement in existing buildings.	Methodological conflict: The methodologies are based on subjective judgement, so there is need for more objective and standardized assessment methods.

Table 2. Cont.

Author and Reference	Type of Research	Objectives	Research Approach	Key Findings	Key Factors in the Study	Review Remarks	Research Gap
Heidari et al., 2017 [21]	Model Advancement	To develop guidelines to enhance ventilation performance of wind-induced ventilation in Sistan’s vernacular architecture.	Qualitative	Provided guidelines to enhance natural ventilation performance in both existing and future buildings in three different compound room types.	Ventilation elements, Room orientation, Wind behavior, satisfaction with indoor environment quality.	The optimizing ventilation strategies in traditional Sistan architecture provided in this research are quite effective.	Methodological conflict: The empirical validation across different environmental contexts is totally.
Batterman (2017) [22]	Model Advancement	To estimate ventilation rates in school classrooms to review and evaluate CO ₂ -based methods and to provide guidance on their application.		The transient mass balance method emerged out to be the best.	Ventilation rate (VR), Indoor environmental quality (IEQ), CO ₂ -based methods, Transient mass balance, HVAC systems.	The study advances improving indoor air quality in schools by using CO ₂ -based methods for estimating VRs and provides practical implications.	Evaluation void: While the transient mass balance method showed promise, evaluation on its accuracy remains incomplete.
Chen et al., 2023 [23]	Model Testing	To enhance thermal comfort and energy efficiency in residential buildings through the evaluation of the impact of building orientation and ventilation strategies.	Quantitative	Improving thermal comfort and reducing energy consumption was possible through cross ventilation, stack effect, and natural airflow strategies.	Building orientation Cross ventilation, Vent openings, Stack effect, Window placement, Natural airflow,	The study effectively evaluates passive design strategies for improving thermal comfort in homes.	Evaluation void: Building types and regions considered are not adequate to assess long-term effectiveness, so further validation is needed.

3. Literature Review

Preliminary literature survey revealed that while several theories have been investigated for their relevance, five of them have repeatedly proven to be quite relevant in the context of research in VRA. These theories have been used by the researchers in the study of the influence of traditional knowledge of construction through VRA in building construction to provide the occupants' comfort, without compromising on the importance of protecting the environment and preserving the local culture and tradition.

The following subsections critically examine five theoretical frameworks that have been repeatedly applied in VRA research. Each framework highlights different dimensions, environmental, cultural, or behavioral, of how vernacular strategies influence SIEQ. Together, they provide the conceptual foundation for this review.

3.1. Sustainability Theory (SUT)

SUT emphasizes balancing ecological resilience, social heritage, and environmental efficiency. In VRA research, it is frequently applied to analyze passive cooling, natural ventilation, and the use of local materials as strategies that reduce energy demand while preserving cultural identity [24–30]. While SUT highlights the environmental and cultural dimensions of sustainability, applications often focus narrowly on energy savings, with limited integration of occupant-centered measures of comfort.

3.2. Bioclimatic Architecture Theory (BAT)

BAT provides principles for achieving thermal comfort through climatic adaptation. Studies across regions—India, Iran, China, Portugal, and Brazil—demonstrate how courtyard planning, orientation, thick masonry walls, and roof overhangs reduce heat gain and improve natural ventilation [31–45]. BAT thus offers a climate-responsive framework closely aligned with adaptive comfort models [36]. However, its applications often emphasize physical performance, with less attention to subjective occupant satisfaction.

3.3. Ecological Systems Theory (EST)

Environmentally responsive design, as endorsed by Ecological Systems Theory (EST), has been instrumental in understanding vernacular architecture (VRA). EST addresses interactions between human activities, cultural practices, and natural environments. For example, vernacular architecture is often influenced by its local ecological context, reflecting adaptation to regional environmental conditions [42]. EST provides a framework for analyzing both micro- and macro-level interactions between nature and human habitation in VRA dwellings [43]. Community resilience to environmental change has been fostered through VRA, in alignment with EST principles [44]. Mazraeh and Mahmoudzadeh (2024) applied EST to study traditional Baber-room construction in Iran, particularly regarding thermal comfort [10]. Fitriaty et al. (2023) used EST to evaluate material selection and natural ventilation in vernacular houses in Indonesia [45]. Yousefniapasha et al. (2021) employed a shape-grammar approach to show how spatial configuration interacts with cultural and environmental contexts, consistent with EST principles [46]. Numerous studies have applied EST in VRA research, reinforcing its relevance in integrating environmental, cultural, and social dimensions.

3.4. Social Cognitive Theory (SCT)

SCT emphasizes learning, social behavior, and community interaction. In VRA studies, it has been used to analyze how traditional spatial arrangements foster identity, adaptation, and collective well-being [11,47–52]. SCT thus foregrounds the role of perception, social norms, and behavioral reinforcement in shaping comfort. However, its integration

with environmental performance measures remains limited, resulting in a fragmented understanding of SIEQ's social dimension.

3.5. Theory of Planned Behavior (TPB)

TPB explains how attitudes, subjective norms, and perceived behavioral control influence the preservation and adaptation of VRA practices. Research shows how norms and community beliefs shape sustainable construction preferences and occupant choices [53–57]. TPB is particularly relevant for understanding how cultural continuity and behavioral intentions affect acceptance of vernacular strategies in modern contexts. Nevertheless, TPB applications in VRA remain few and often context-specific, leaving scope for broader generalization.

3.6. Synthesis of Theories

Taking together, these five frameworks demonstrate that VRA's contribution to SIEQ is multidimensional: environmental theories (SUT, BAT, EST) explain physical and ecological performance, while behavioral theories (SCT, TPB) capture social and cultural determinants of satisfaction. Despite their widespread application, no study integrates all five into a unified model, underscoring the need for comprehensive frameworks that bridge environmental, cultural, and behavioral dimensions.

3.7. Variable Clustering and Synthesis

In parallel with theoretical perspectives, a synthesis of variables was undertaken to capture how specific design features of vernacular houses contribute to satisfaction with indoor environmental quality (SIEQ). A total of 62 variables cited across the reviewed studies were systematically consolidated into eight thematic clusters. The clustering process followed a multi-stage approach, employing a single linkage grouping method to combine variables with shared operational definitions. This approach reduces fragmentation in literature and highlights recurring design features that shape SIEQ outcomes. The resulting framework provides a coherent structure for analyzing the antecedents of SIEQ and is presented in Table 3.

Table 3. Cluster, research constructs, variables, and contributing authors.

Cluster	Research Construct	Variables from Review Articles	Number of Times Cited	Contributing Authors
1.	Natural Ventilation (NVN)	Cross ventilation	10	[6,21,23,30,58–60]
		Vent openings	8	[21,58–63]
		Stack effect	7	[21,58–60,62,63]
		Window placement	6	[1,15,23,60,64,65]
		Natural airflow	9	[15,21,38,58,59,66]
		Orientation to wind direction	5	[10,20,67,68]
		Operable windows	8	[19,67,69]
2.	Orientation and Layout (ORL)	Building orientation	7	[10,20,37,39,67,70–73]
		Spatial layout	6	[46,70,71,74–77]
		Zoning (function, privacy, accessibility)	5	[8,20,57,70,78,79]
		Thermal zoning	7	[62,67,80–82]
		Floor plan configuration	9	[8,40,67,68,83,84]
		Proximity to open spaces	8	[57,65,85–87]
		Room arrangement	7	[88–92]
		Sun path alignment	6	[20,64,67,68]

Table 3. Cont.

Cluster	Research Construct	Variables from Review Articles	Number of Times Cited	Contributing Authors
3.	Use of Local Materials (ULM)	Locally sourced wood	12	[9,16,40,93–95]
		Laterite stone usage	9	[9,57,79,96,97]
		Bamboo materials	8	[10,41,86,94,96]
		Stone masonry	8	[16,79,81,98]
		Terracotta bricks	6	[10,40,96]
		Mud walls	7	[9,85,86,94]
		Clay tiles	6	[67,68,79,89,99]
		Thatch roofing	5	[9,100–102]
		Recycled materials	8	[16,65,71,103,104]
4.	Shading Devices (SHD)	Roof overhangs	5	[40,59,79,90,105]
		Plant-based shading	4	[68,71,86,98,101]
		Courtyard trees	6	[79,86,90,94]
		Louvered screens	7	[21,80,87,89]
		Verandas	8	[81,86,89,94,101]
		Canopies	9	[3,16,45,100]
		Pergolas	5	[3,59,78]
5.	Perceived Thermal Comfort (PTC)	Temperature regulation	11	[1,15,16,21]
		Heat dissipation	7	[16,21,45,59,94]
		Radiative cooling	6	[3,106,107]
		Humidity control	6	[21,80,81,107]
		Thermal insulation	8	[3,16,93,94]
		Adaptive clothing	9	[22,89,100,107]
		Cooling through evaporation	5	[16,21,45,81]
6.	Perceived Air Quality (PAQ)	Seasonal adaptability	7	[59,80,100]
		Indoor air freshness	8	[2,3,22,61,66,108]
		Natural filtration	6	[3,16,63,66]
		Ventilation rate	5	[3,19,93,107–109]
		Dust reduction	7	[3,19,22,80]
		Airflow distribution	7	[19,21,66]
		Carbon-dioxide levels	8	[3,16,21,22]
		Removal of indoor pollutants	9	[19,22,107]
7.	Perceived Natural Lighting (PNL)	Humidity moderation	6	[3,16,19,80]
		Daylight penetration	9	[3,59,100,110,111]
		Glare control	5	[19,21,80,107,111]
		Window-to-wall ratio	8	[2,3,19,22,111]
		Light shelves	6	[2,3,16,19,100]
		Sunlight redirection devices	6	[3,66,81,89]
		Diffuse lighting	7	[21,22,107]
		Interior reflectance	8	[3,16,66,89,100,107]
8.	Satisfaction with Indoor Environmental Quality (SIEQ)	Time of light availability	6	[3,16,19,100]
		Thermal comfort satisfaction	15	[19–21,59,67,98]
		Air quality satisfaction	12	[59,80,89,93]
		Visual comfort satisfaction	14	[2,19,21,100,107]
		Acoustic comfort satisfaction	10	[19,22,89,107]
		General occupant satisfaction	18	[2,3,86,100]
		Energy efficiency perception	11	[16,19,21,22,107]
Total		Health and well-being perception	13	[3,16,19,21,89,112]
			484	

4. Results

This section presents the findings of the systematic literature review (SLR), organized in alignment with the study objectives. The results are reported in a structured narrative to answer the research questions: (i) Which theoretical frameworks are most frequently applied to explore VRA and SIEQ? (ii) How are research focuses and types distributed across the literature? (iii) How can variables be clustered to conceptualize antecedents of SIEQ? and (iv) What research gaps remain? The dataset of 105 reviewed papers provided insights across three main dimensions: theoretical applications, research focus and type, and variable clustering. The distribution of studies by country, database, and body indexing was also analyzed to establish context.

4.1. Distribution of Studies

4.1.1. Geographical Distribution of Papers

The regional distribution of studies on vernacular architecture reveals a wide geographical spread, with India contributing the largest share at 17.5%, followed by Iran at 15.5% (Figure 2). The UK accounts for 11.7%, while both the USA and China contribute 7.8% each. This distribution underscores the importance of focusing on regions with rich architectural heritage and diverse climatic conditions when examining vernacular architecture. Other notable contributions come from countries such as Egypt, Mexico, Turkey, and Indonesia, reflecting the global interest in environmentally sustainable and culturally relevant building practices. The inclusion of European nations such as Portugal, Spain, and Italy, along with Brazil from South America, further demonstrates the widespread recognition of vernacular architecture's value. Overall, the SLR highlights the significance of regional studies in understanding the concepts and practices of vernacular architecture across varied geographical and cultural contexts.

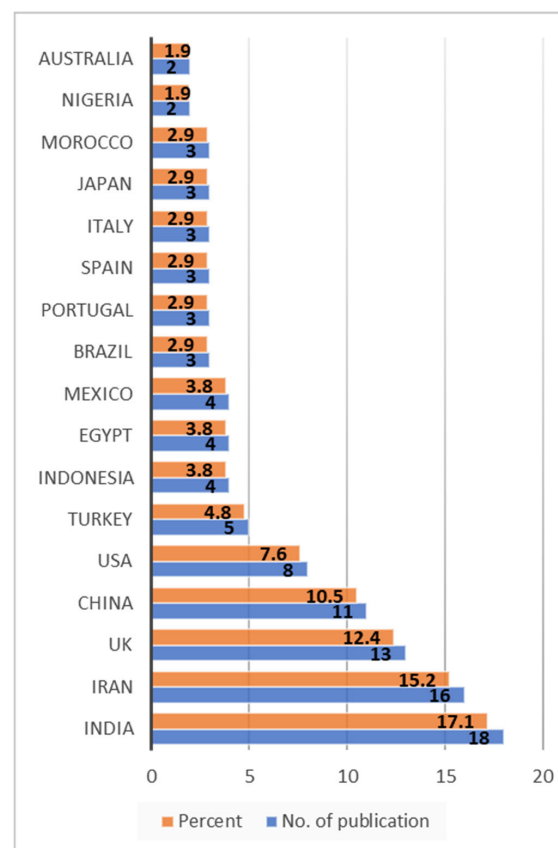


Figure 2. Geographical distribution of papers.

4.1.2. Databases Utilized for the Study

With 105 publications examined, the analysis reveals a diverse distribution of research sources across major academic databases. Scopus emerged as the leading repository, accounting for 31.4% of all publications (Figure 3), reflecting its broad coverage and strong relevance to the topic. Clarivate Analytics ranked second, contributing 21.9% of the identified works on VRA. This was followed by ProQuest (14.3%) and EBSCO (10.5%). SAGE and JSTOR contributed 6.7% and 3.8%, respectively, while all remaining databases collectively accounted for only 1.9% of the publications. This distribution underscores the dominance of a few major indexing platforms in disseminating scholarly research on vernacular architecture.

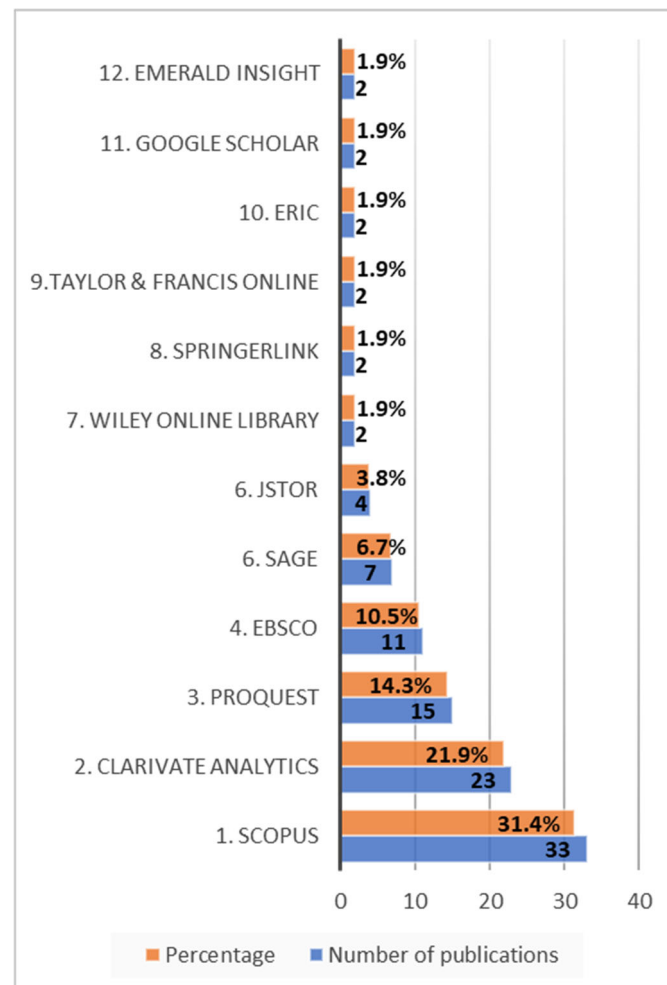


Figure 3. Distribution of papers based on database.

4.1.3. The Indexing Agencies of Papers

Among the indexing agencies, Scopus contributed the largest share, comprising 31.4% of the total publications (Figure 4). Google Scholar accounted for 17.1%, followed by Web of Science (15.2%), EMBASE (14.3%), EBSCO (11.4%), and ProQuest (10.5%). This distribution indicates that the majority of publications originate from databases indexed by leading global indexing bodies, reflecting the credibility and scholarly rigor of the reviewed literature.

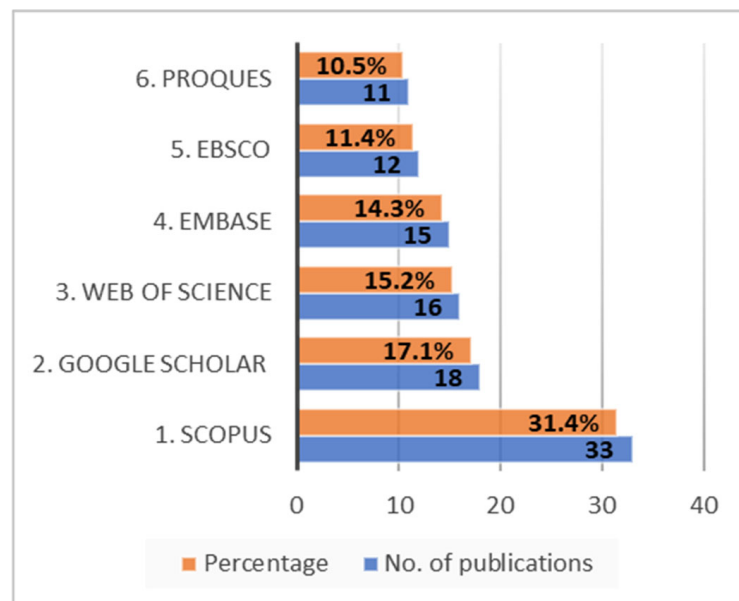


Figure 4. Distribution of papers based on Indexing Bodies.

4.2. Theoretical Applications

Theories most frequently applied in Vernacular Architecture (VRA) research include Sustainability Theory (38%), Bioclimatic Architecture Theory (24%), and Ecological Systems Theory (21%), followed by Social Cognitive Theory (10%) and the Theory of Planned Behavior (10%) (Figure 5). The dominance of environmental and climatic frameworks—collectively representing 83% of theoretical applications—demonstrates a strong disciplinary focus on understanding how design elements influence satisfaction with indoor environmental quality (SIEQ) through environmental, climatic, and ecological perspectives. However, the relatively limited use of SCT and TPB suggests that the social, behavioral, and cognitive dimensions of human–environment interaction remain underexplored. Developing an integrative model that synthesizes insights from both environmental and social-behavioral theories would enable a more holistic understanding of how physical design, human perceptions, and behavioral patterns interact to shape SIEQ in VRA. Such a framework would bridge existing theoretical gaps, ensuring that both environmental performance and occupant experience are fully addressed in the pursuit of enhancing SIEQ through vernacular design.

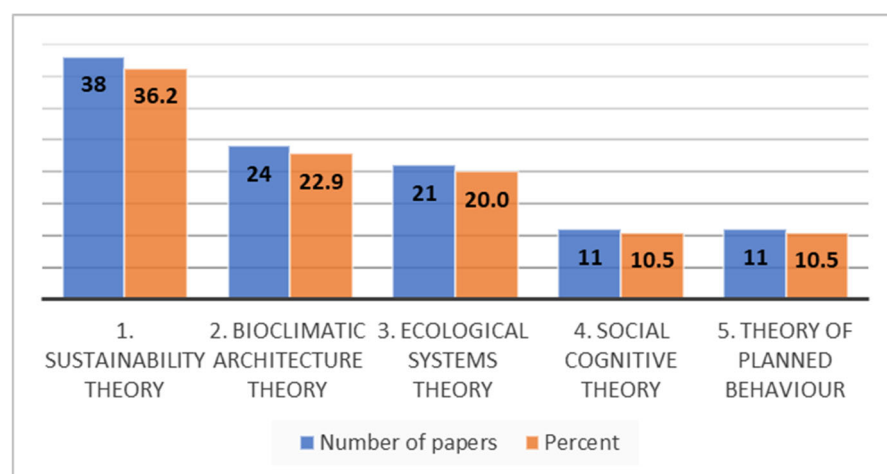


Figure 5. Distribution of papers based on contribution to theories.

4.3. Research Focus and Research Type

4.3.1. Research Approaches Used in the Papers

With 58.1% of the publications employing this strategy (Figure 6), the distribution of articles by research methodology in vernacular architectural studies reveals a clear preference for qualitative approaches. This dominance reflects the discipline's emphasis on in-depth, context-specific investigations of architectural practices, often utilizing case studies, interviews, and ethnographic methods to explore the cultural, social, and environmental dimensions of vernacular architecture. Quantitative approaches, used in 28.6% of studies, focus on the collection of empirical data and statistical analysis, typically to evaluate the structural characteristics or environmental performance of vernacular buildings. Mixed method approaches account for 13.3%, integrating quantitative data with qualitative insights to provide a more holistic understanding. Overall, the distribution underscores the centrality of qualitative inquiry in capturing the nuanced and context-rich nature of vernacular architecture, while quantitative and mixed methods play an important role in validating and reinforcing findings.

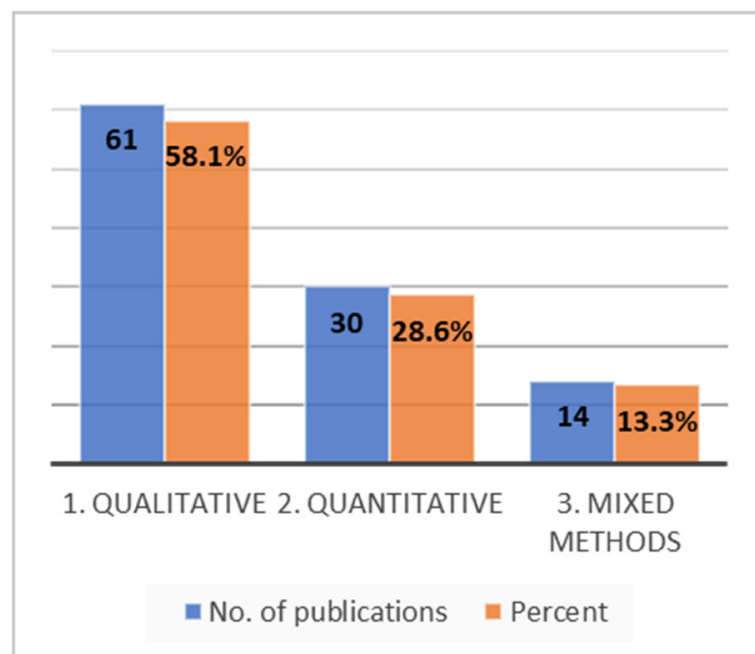


Figure 6. Distribution of papers based on research approach.

4.3.2. Research Focus

Model testing emerged as the most prevalent research type, accounting for 35.2% of the 103 reviewed papers (Figure 7). The substantial representation of Model Advancement (32.4%) underscores ongoing efforts to refine and improve existing frameworks in response to the dynamic nature of the field. In contrast, Model Development and Model Integration—each constituting 16.2%—are comparatively less explored. This imbalance suggests that while testing and advancing established models remain the dominant focus, there is considerable scope for expanding research on developing new models and integrating multiple theoretical perspectives. Combining the prominent theories discussed earlier could foster the creation of robust integrative models that better address the complexities of SIEQ in the context of vernacular architecture.

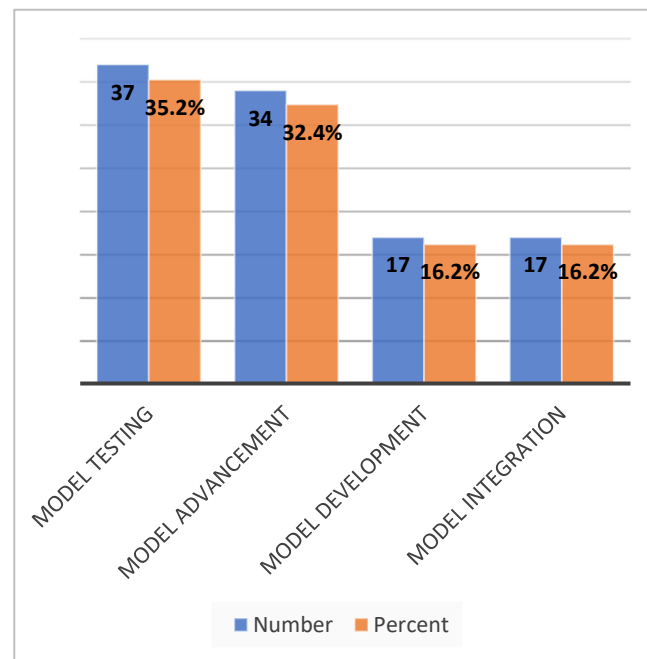


Figure 7. Distribution of papers based on research focus.

4.3.3. Research Type

The 105 papers reviewed in this SLR on vernacular architecture (VRA) demonstrate a diverse range of methodological approaches. Grounded theory is the most frequently employed, appearing in 25.7% of studies (Figure 8), underscoring the emphasis on developing theories rooted in the VRA context to uncover underlying patterns and meanings. Descriptive studies account for 22.9%, reflecting a strong focus on classifying and characterizing the various elements of VRA. Case studies (20%) highlight the value of context-rich, in-depth examinations of individual examples, offering nuanced, site-specific insights. Document analysis (14.3%) and empirical research (13.3%) further contribute historical depth and fact-based perspectives. Analytical research, the least represented at 3.8%, reflects more targeted investigations into specific aspects of VRA through rigorous data analysis. This distribution suggests the need for a balanced approach that integrates theoretical development, descriptive categorization, and empirical validation to advance understanding of VRA's complex dynamics. To synthesize these insights, a Research Focus Map (Figure 9) was developed, illustrating contribution types in relation to the applied theories, four stages of research focus, and the six research types identified in the literature.

A Research Focus Map was developed to classify the 105 reviewed studies, with 17 addressing model development, 37 model testing, 34 model advancement, and 17 model integration (Table 2). The most frequently applied framework was Sustainability Theory (SUT, 38 papers), followed by Bioclimatic Architecture Theory (BAT, 24), Ecological Systems Theory (EST, 21), and both Social Cognitive Theory (SCT) and the Theory of Planned Behavior (TPB) (11 each) (Figure 10). SUT and BAT dominated model testing and advancement, whereas SCT and TPB were underrepresented in development and integration.

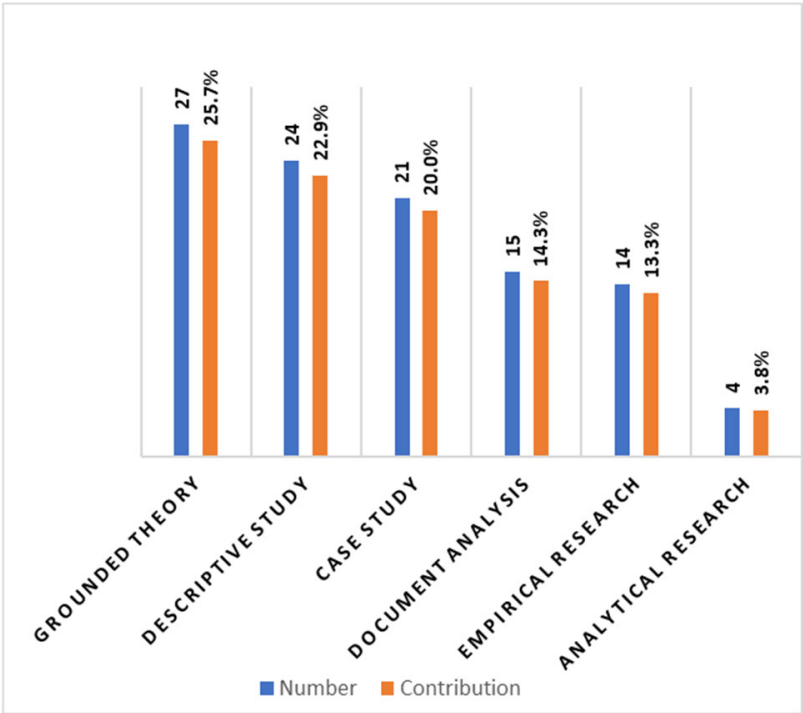


Figure 8. Distribution of papers based on research methods.

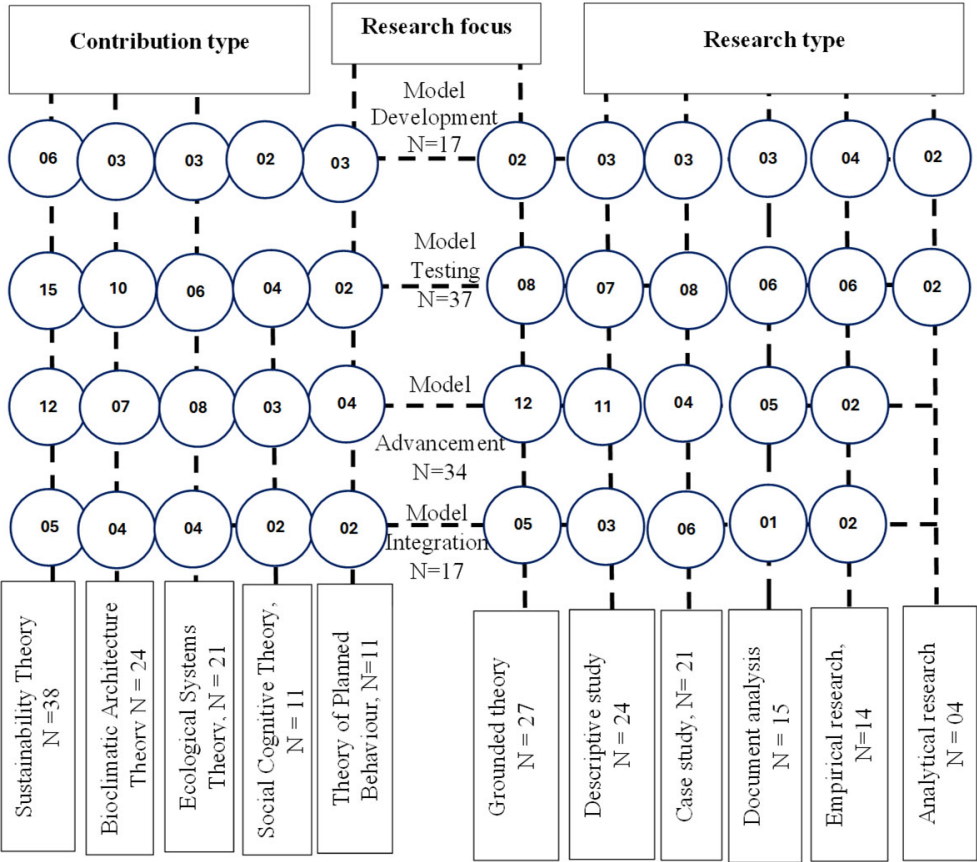


Figure 9. The research focus map.

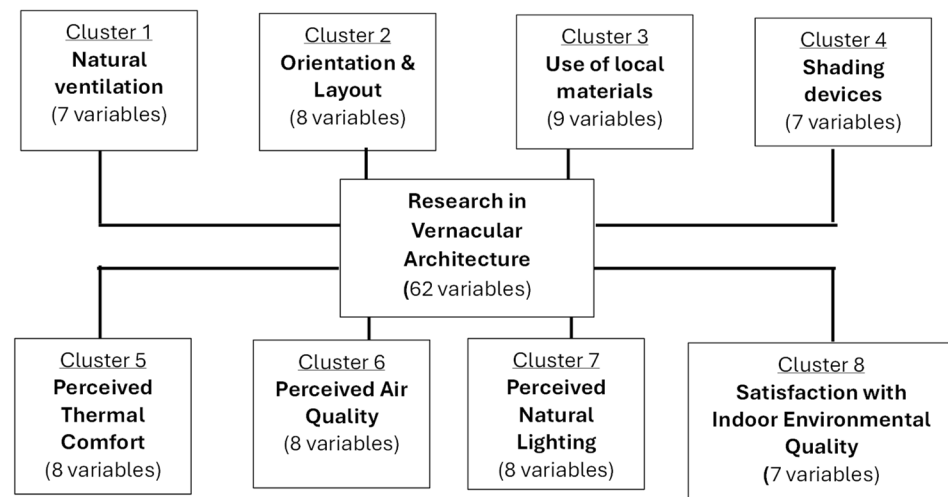


Figure 10. Cluster classification of research in vernacular architecture.

Grounded theory (27 studies) was the most common research type, particularly in model development and advancement, followed by descriptive (24), case studies (21), document analysis (15), empirical (14), and analytical (4). Overall, model testing and advancement predominate, while integrative studies combining all five theoretical frameworks remain absent, representing a key research gap.

Among theories, SUT was most widely applied as it links vernacular residential architecture (VRA) with sustainability objectives, such as reducing energy demand through passive design [15,113]. BAT followed, emphasizing thermal comfort under varying climatic conditions [37,67] and highlighting climate-responsive strategies [58,59]. EST contributed ecological perspectives, particularly on the cultural and environmental implications of modern transformations of VRA [80,88,114,115]. Though less frequent, TPB offered insights into behavioural aspects, including social norms, attitudes, and intentions of residents [2,74].

4.4. Variable Clustering

Identification of Variables Using Cluster Analysis

The systematic literature review (SLR) revealed that research on satisfaction with indoor environmental quality (SIEQ) in vernacular residential architecture (VRA) suffers from several gaps—namely, the knowledge void, evaluation void, and methodological conflicts. These gaps reflect a lack of integrated understanding of how diverse design features collectively influence SIEQ. To bridge this, we adopted cluster analysis, an exploratory method that organizes similar data items into groups based on their shared characteristics. By grouping variables that have been studied in fragmented ways, cluster analysis provides a structured framework for identifying patterns and relationships, thereby helping to clarify the key factors influencing SIEQ. This approach not only synthesizes existing knowledge but also guides future research by offering a coherent set of variables for comprehensive study.

Our SLR extracted 62 distinct variables, referenced 484 times across 105 studies (Table 3), and manually grouped them into eight clusters (Figure 10). The clusters are summarized below:

1. Natural Ventilation (Cluster 1): 7 variables related to passive airflow strategies: cross ventilation, ventilation openings, stack effect, window placement, natural airflow, orientation to prevailing winds, and operable windows.
2. Orientation and Layout (Cluster 2): 8 variables capturing spatial and solar positioning: building orientation, spatial layout, functional zoning (privacy/accessibility), thermal

- zoning, floor-plan configuration, proximity to open space, room arrangement, and sun-path alignment.
3. Use of Local Materials (Cluster 3): 9 variables reflecting vernacular material choices: locally sourced wood, laterite stone, bamboo, terracotta bricks, mud walls, clay tiles, thatch roofing, and recycled materials.
 4. Shading Devices (Cluster 4): 7 variables involving shading and buffering: roof overhangs, plant-based shading, courtyard trees, louvered screens, verandas, canopies, and pergolas.
 5. Perceived Thermal Comfort (Cluster 5): 8 variables describing how occupants experience thermal conditions: temperature regulation, heat dissipation, radiative cooling, humidity control, thermal insulation, adaptive clothing, evaporative cooling, and seasonal adaptability.
 6. Perceived Air Quality (Cluster 6): 8 variables related to ventilation and air freshness: indoor air freshness, natural filtration, ventilation rate, dust reduction, airflow distribution, carbon dioxide levels, pollutant removal, and humidity moderation.
 7. Perceived Natural Lighting (Cluster 7): 8 variables concerning daylighting strategies: daylight penetration, glare control, window-to-wall ratio, light shelves, sunlight redirection devices, diffuse lighting, interior reflectance, and time of light availability.
 8. Satisfaction with IEQ (Cluster 8): Seven variables capturing overall satisfaction: thermal comfort satisfaction, air quality satisfaction, visual comfort satisfaction, acoustic comfort satisfaction, general occupant satisfaction, energy-efficiency perception, and health-and-well-being perception.

An integrative model summarizing the theoretical underpinnings, thematic clusters, and identified research gaps is presented in Figure 11.

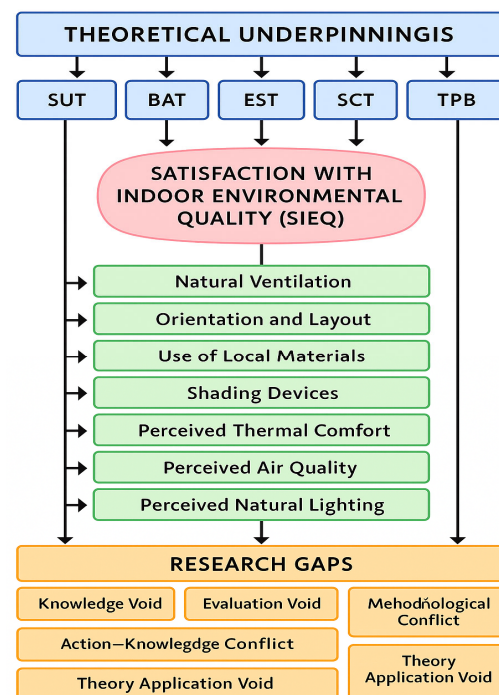


Figure 11. Integrative model summarizing theoretical underpinnings, thematic clusters of design features, and research gaps identified in the SLR.

4.5. Research Gaps

Identification of the Research Gaps

Within the reviewed literature, six categories of research gaps were identified: knowledge void, evaluation void, methodological conflict, action-knowledge conflict, theory application void, and theory application void.

application void, and contradictory evidence [116–119]. Among these, the most critical are the evaluation void (57 occurrences), methodological conflict (15), and theory application void (5), reflecting limited empirical validation, inconsistencies in measurement protocols, and insufficient theoretical grounding in existing studies. The remaining categories—knowledge void, action–knowledge conflict, and contradictory evidence were less frequent but remain relevant for future inquiry. A detailed account of these gaps, their associated deficiencies, and proposed research directions is presented in Table 4. These trends underscore the limited empirical validation, methodological inconsistencies, and underutilization of theory that currently constrain the field, forming the basis for the implications discussed in Section 5.

Table 4. The type of research gap, deficiencies, need to bridge the gap, contributing authors, and future direction for research.

Research Gap	Deficiencies	Need to Bridge the Gap	Key Contributing Authors	Directions for Future Research
RG1. Knowledge void	Lack of thorough, integrated research examining the relationships between environmental quality, sociocultural views of residents, and architectural design elements.	To advance the theoretical and practical understanding. The research can help create more efficient and culturally aware architectural designs that improve SIEQ and occupant happiness.	[1,8,15,45,67,82]	• Develop integrative models of VRA design with social and cultural values. • Investigate the role of sociocultural factors on environmental quality in architectural practices. • Study the role of cultural diversity in forming the perception of environmental quality in vernacular designs. • Investigate how VRA can be used in improving environmental sustainability.
RG2. Evaluation void	Dearth of empirical evidence or assessments of the ways in which different VRA design elements affect SIEQ.	Filling this research gap is crucial for developing evidence-based guidelines that can inform the design of future vernacular-inspired buildings, ensuring they meet modern SIEQ standards while preserving cultural heritage.	[1,17,20,43,85,120]	• Assess SIEQ through comparative studies between modern and vernacular designs. • Integrate vernacular design elements in modern architectural designs and explore the improvement of SIEQ, if any. • Conduct comparative studies of SIEQ in vernacular architecture across different climatic conditions. • Use technology and simulations to assess the impact of VRA design elements on SIEQ.
RG3. Methodological conflict	Discrepancies or contradictions in the findings based on methods applied in several studies across regions, contexts, and settings.	To provide unified or comparative methodological framework that can address these discrepancies, yield more dependable and generalizable results, and improve the consistency and comparability of study findings, resulting in a better comprehension of how VRA affects SIEQ	[15,18,20,82,91,121]	• Standardize the methodology exclusively for evaluating SIEQ in VRA. • Explore mixed-methods approach to bridge discrepancies in the findings of the impact of VRA on sustainability. • Conduct cross-cultural studies to compare SIEQ in vernacular architectures across regions to find methodological consistency/inconsistencies.
RG4. Action-knowledge conflict	Disparity between study findings (knowledge of SIEQ) and practical use of that information (VRA application).	To ensure that the important insights obtained from research on VRA are successfully transformed into realistic, sustainable architectural practices, hence improving SIEQ.	[10,45,66,85,88,93]	• Test the VRA design under a greater number of real-life situations. • Develop case studies to show how VRA principles are implemented in real-world projects to improve SIEQ. • Develop policy guidelines to promote the practical application of research findings in VRA designs. • Develop educational content on VRA designs and connect researchers with architects to implement research-based solutions.

Table 4. Cont.

Research Gap	Deficiencies	Need to Bridge the Gap	Key Contributing Authors	Directions for Future Research
RG5. Theory application void	Insufficient use or incorporation of current theories in the investigation of VRA and its influence on SIEQ.	Plugging this gap will provide a stronger theoretical foundation that can direct future studies and real-world architectural applications, which makes it imperative to fill. By filling this gap, scholars can create approaches that improve SIEQ in vernacular architecture while remaining theoretically and practically sound.	[65,85,104,107,122,123]	• Explore and apply a higher number of existing environmental theories to VRA for better results in SIEQ. • Investigate the relationship between theories through empirical studies e.g., the Theory of Planned Behavior (TPB) and environmental comfort in VRA. • Explore theories such as the Social Cognitive Theory (SCT) in the context of enhancing SIEQ across cultures. • Promote research on interdisciplinary approaches (e.g., psychology, sociology) to refine theoretical models for VRA and SIEQ.
RG6. Contradictory evidence	Disparities or contradictory results on the relationship between VRA and SIEQ because of variations in regional circumstances, or theoretical frameworks utilized.	To develop more trustworthy evidence and more precise instructions for integrating VRA into contemporary building practices by addressing these conflicts, which would ultimately improve SIEQ in a variety of climatic and cultural contexts.	[2,8,17,19,67,100]	• Conduct meta-analysis to compare findings from different studies. • Conduct longitudinal research to test the relationship between VRA and SIEQ. • Explore alternative theoretical frameworks and models on the understanding of VRA and SIEQ.

5. Discussion

This section interprets the findings of the SLR, considering existing literature, emphasizing theoretical, methodological, and practical implications.

5.1. Interpretation of Findings

The dominance of SUT and BAT reflects a strong emphasis on environmental and climatic dimensions of VRA, whereas SCT and TPB remain underrepresented. This imbalance highlights the need for integrative approaches that combine environmental and behavioral dimensions. The clustering of variables into eight themes demonstrates that although diverse factors have been studied, their fragmented treatment limits the development of unified models.

5.2. Comparison with International Literature

Findings align with international studies on vernacular design and indoor comfort [insert references from your draft here]. However, compared to other regions (e.g., Mediterranean, Middle East, Southeast Asia), Indian studies remain less integrated in theoretical application, signalling an area for improvement.

5.3. Implications of the Study

The identification of research gaps carries direct implications for both practice and policy. For architects and planners, the findings highlight the need to adopt integrative frameworks that combine passive design strategies with user-centered evaluation of comfort. Addressing the evaluation void requires systematic post-occupancy evaluations to generate evidence-based design guidelines for climate-responsive housing. Tackling methodological conflict calls for standardized protocols for measuring SIEQ variables, enabling more reliable cross-study comparisons. Bridging the theory application void demands greater integration of sustainability, ecological, and behavioral frameworks into design practice. For policymakers, these insights underscore opportunities to embed vernacular strategies into building codes and sustainability standards. Collectively, responding to these gaps can help translate research into actionable strategies that enhance the resilience, comfort, and sustainability of both vernacular and contemporary housing.

5.4. Strengths and Limitations

This review makes a significant contribution by integrating theoretical, methodological, and variable-level synthesis across seven decades of scholarship, offering a comprehensive overview of VRA–SIEQ research. By consolidating five widely applied theories, clustering 62 variables into eight themes, and identifying six categories of research gaps, the study establishes a structured foundation for advancing future inquiry.

However, certain limitations must be acknowledged. First, the scope of the review was restricted to studies published in the past two decades, which may have excluded earlier work that remains relevant. Second, the inclusion criteria were limited to publications in English, potentially omitting valuable research in other languages. Third, while six principal types of research gaps were identified, this categorization may not capture all possible perspectives, as alternative frameworks could reveal additional gaps. Fourth, the focus on five prominent theories necessarily excluded other, less explored frameworks that may also influence SIEQ. Finally, although the PRISMA-guided process ensured rigor, the possibility remains that relevant studies were inadvertently overlooked.

Despite these limitations, the study provides a solid foundation by mapping theoretical contributions, classifying research approaches, and highlighting actionable gaps. These strengths reinforce its value for guiding both future research and the practical adoption of climate-responsive design strategies.

5.5. Future Research Directions

Future studies should focus on empirical validation of integrated frameworks, cross-cultural comparisons, and the operationalization of clusters into measurable indicators of SIEQ.

6. Conclusions

This review advances understanding of vernacular residential architecture (VRA) and satisfaction with indoor environmental quality (SIEQ) by systematically synthesizing evidence from 105 studies. Key findings can be summarized as follows:

- **Theoretical Contributions:** Five major frameworks: SUT, BAT, EST, SCT, and TPB were identified, with SUT and BAT most widely applied, while SCT and TPB remain underutilized.
- **Research Focus and Types:** The literature is dominated by model testing and advancement, with fewer contributions in model development and integration. Grounded theory was the most frequently applied methodological approach.
- **Variable Clustering:** Sixty-two variables were consolidated into eight thematic clusters, providing a structured foundation for conceptualizing the antecedents of SIEQ.
- **Research Gaps:** Six categories of gaps were identified, with evaluation void, methodological conflict, and theory application void emerging as the most critical.

By consolidating theoretical perspectives, clustering variables, and mapping research gaps, this review provides a comprehensive framework for advancing both scholarship and practice. For architects and planners, the findings highlight the need for integrative, evidence-based design strategies. For policymakers, they underscore opportunities to embed vernacular principles in building codes and sustainability standards. Collectively, the study offers actionable pathways to enhance resilience, comfort, and sustainability in contemporary housing.

The significance of this study lies in its contribution to the ongoing dialogue linking sustainability, architectural design, and occupant well-being. In an era of escalating climate change and rapid urbanization, vernacular traditions emerge not as relics of the past but as vital resources for shaping resilient, culturally resonant, and climate-responsive housing.

By bridging vernacular wisdom with contemporary sustainability imperatives, this review demonstrates that traditional architectural knowledge is indispensable for shaping the future of resilient housing. The findings also align with and extend recent bibliometric and conceptual contributions in vernacular and sustainable design [124,125]. Furthermore, the clarity and scholarly rigor of this manuscript were enhanced by drawing on recommended practices in scientific writing for non-native speakers [126].

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Abbreviations

The following abbreviations are used in this manuscript:

SLR	Satisfaction with Indoor Environmental Quality
VRA	Vernacular Architecture
SUT	Sustainability Theory
BAT	Bioclimatic Architecture Theory
EST	Ecological Systems Theory
SCT	Social Cognitive Theory
TPB	Theory of Planned Behavior
IEQ	Indoor Environmental Quality
SIEQ	Satisfaction with Indoor Environmental Quality

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