

Research Article

# Studies on sustainable features of vernacular architecture in different regions across the world: A comprehensive synthesis and evaluation



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## KEYWORDS

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Traditional architecture;  
Sustainable feature;  
Research method;  
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**Abstract** Due to the increasing pressure brought by recent global environmental problems, building designers are embracing regionalism and the knowledge of traditional structures, arguing that these structures are energy efficient and highly sustainable. We observe clear evidence of the increasing interest in vernacular architecture among the research community. This study therefore aims to clarify the contents and issues raised in the studies on vernacular architecture and the knowledge and recommendations that can be derived from them. A database of the research is established by collecting many studies from primary sources. Obtained data is carefully refined and categorized into a table where synthesized information is introduced. The results of this study show an uneven geographic and climatic distribution of the studies; the trend in selecting research objectives and research objects; the choice of research methods with a clear shift towards quantitative research methods, and the generic findings from the database of the research. These results can support diverse inquiries about vernacular architecture across the world and be used as a resource or an orientation to support numerous subsequent studies.

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## 1. Justification of the research question

During thousands of years, the inhabitants of each region of the world have evolved bioclimatic methodologies and systems for mitigating the effects of adverse weather conditions of the local climate. Solutions for each region are directly reflected in the forms of clothing worn, the diurnal-nocturnal work patterns, and the construction of buildings and the activities undertaken within them (Al-Hinai et al., 1993). The origin of bioclimatic design in architecture can be traced back to the design principles applied in most vernacular or traditional buildings around the world. Vernacular/traditional architecture (for simplicity, hereafter we use the term “vernacular architecture”) evolved over time, reflecting environmental, cultural, technological, and historical context of a specific location on which it was built (Nguyen and Reiter, 2017). Thus, vernacular architecture is believed to be well adapted to local climate and nature, thus embodying a comprehensive wisdom (see Fig. 1).

Conveying this wisdom from our ancestors to present, and from present to the future generations would exhibit a deep respect for nature, environment, and traditional culture. There is an increased recent interest in the research community on the sustainable features of vernacular architecture. This is a result of the need to respond to climate change, environmental pollution, and the desire to decrease energy consumption.

Fig. 2 presents the increased trend of international studies on vernacular architecture (127 studies indexed by SciVerse Scopus of Elsevier and Google scholar that the authors could obtain) within the last three decades. It was observed that the annual number of studies has shown a sharply increased trend since the year 2007. This indicates a greater interest on sustainable features of vernacular architecture and their potential applications among the building research community.

The present study aims to analyze and clarify the achievements of the collected studies on vernacular architecture and the lessons derived from them. Challenges and potential trends of this research area will also be discussed. The findings of this study are expected to provide potential research orientations and useful information on materials and methods for other similar studies. In

addition, the underlying aim of this paper is to document the origins, scope, techniques, contents, results, and quick accessibility of studies on sustainable features of vernacular architecture worldwide.

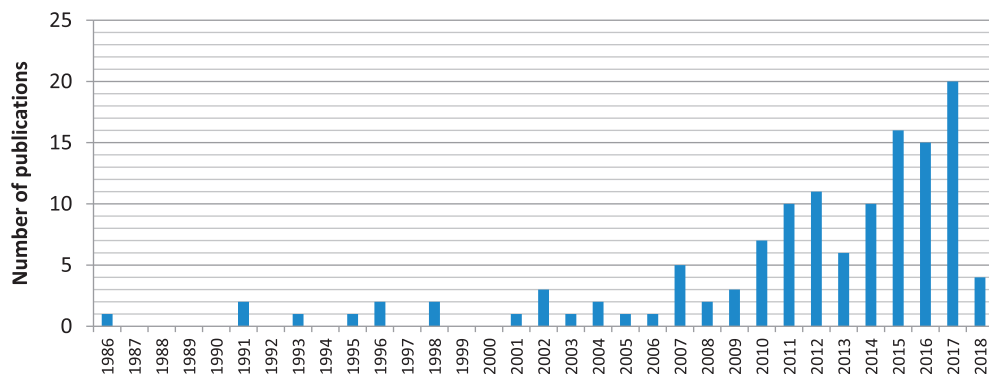
This study found that a diversity of terms is used to reference vernacular/traditional architecture, including: historical, traditional, ancient, vernacular, folk architecture (dwellings, buildings, settlements, and urban fabrics). This study therefore addresses, but is not restricted to, the main theme on vernacular architecture because there is a large body of research which covers both vernacular architecture and vernacular settlements and urban fabrics as well as occupants' lifestyles.

## 2. Research methodology

This study employed the archival research method. This involves the investigation of primary sources held in an archive, a special collections library, or other repository. The archival research method is one of the common methods applied to architecture studies as carefully described in section 3.4.1. We collected studies on sustainable features of vernacular architecture from two primary databases: Scopus and SpringerLink. These are the resources where the authors were granted the access right. Other studies were also obtained from open sources such as Google Scholar, or by contacting authors directly. To reduce the possibility of omitting key information, different keywords were repeatedly applied in the searches in these databases in August 2018. The intention was not to attempt to collect all relevant research as this is not possible. However, the attempt was made to collect highly cited or easily seen (by scientific search platforms) studies, forming a fairly large set of samples with a good representation of contributions relevant to the research area. This large set was filtered out to eliminate inappropriate and/or duplicated studies. We found that some authors published two (even three) papers in both a conference and a journal, but the content of these papers was similar or even homogeneous. In such a case, we only selected the journal paper. Some review papers on vernacular architecture were also excluded as they do not focus on any specific region, climate or specific local structure.



**Fig. 1** The ecological beauty of traditional beehive huts of Zulu people, South Africa (left) and a vernacular settlement of Co-Tu ethnic group, Vietnam (right).



**Fig. 2** Evolution of the number of publications on sustainable features in vernacular architecture over time (data collected until August 2018).

Finally, a total of 127 studies were collected, including papers, theses, books, and articles in recognized conference proceedings, forming thereby a relatively large sample of studies. For each study, we collected the most important information, including: author names and title of the study, year of publication, sites of the study, related geographic and climatic regions, types of investigated buildings, research objectives, description of research methods, research method classification, and key findings of the study. Obtained data were refined and categorized into a table (see [Supplementary data](#)) where synthesized information was analyzed, and crucial findings of this study were derived. The whole process can be divided into 3 phases as described in [Fig. 3](#).

### 3. Results of the analysis, synthesis and evaluation

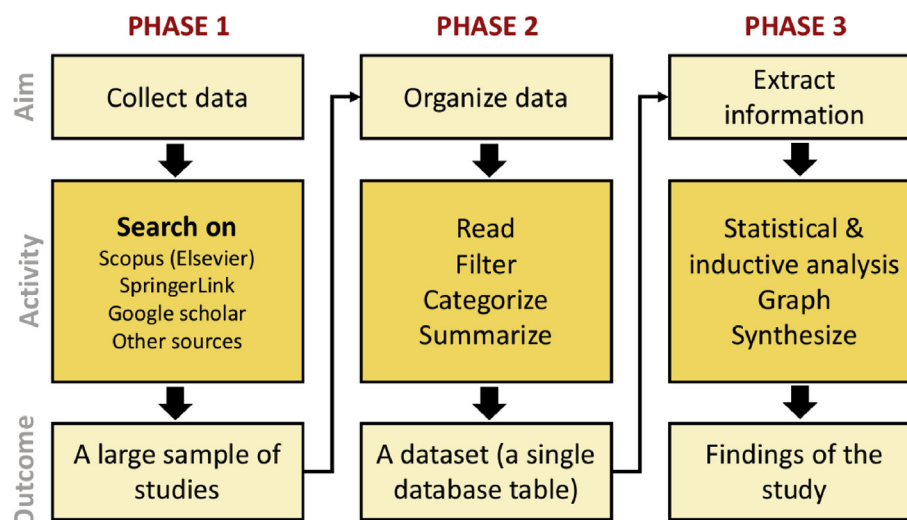
#### 3.1. Geographic and climatic distribution of the studies on vernacular architecture

In this study we investigate the distribution of the studies in the collected set of samples on the continents, geographic regions, and climate zones. The climatic regions are

derived from an improved system of [Beck et al. \(2018\)](#) on the basis of the Köppen – Geiger climate classification system ([Köppen, 1936](#)). The purpose of this analysis is to help researchers detect geographic and climate gaps in the research on vernacular architecture, contributing to the orientation of future research.

[Fig. 4](#) shows a significant amount of research on vernacular architecture in Asia and Europe while in the remaining continents, there are considerably fewer scientific publications on the topic. [Fig. 5](#) details the evolution of publications in Asia, Europe and other regions. In our database, the first study on vernacular architecture was found in Yemen in 1986 ([Al-Motawakel et al., 1986](#)). Five years later, vernacular architecture was nearly forgotten as we have not found any study through this period. Until 1996, studies were only found in the Middle East and East Asia. In Asia and Europe, the high number of studies in the last 10 years indicates that there was a great interest in vernacular architecture in the research community. This increased interest may serve to reinforce the preservation of cultural and natural values of the vernacular human heritage.

[Fig. 6](#) shows a map with the geographic distribution and density across the world of the 127 studies investigated. For ease of displaying this information, each study on



**Fig. 3** The diagram explains the workflow and the research methods employed in the study.

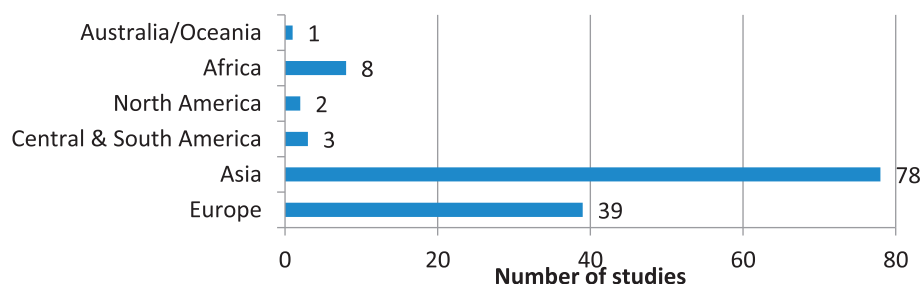


Fig. 4 Distribution of the studies by continents.

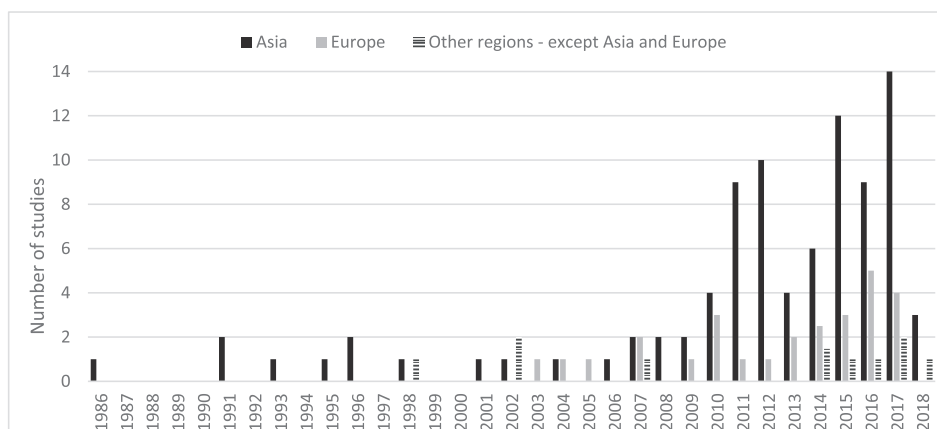


Fig. 5 Number of studies on vernacular architecture over time in key regions of the world.

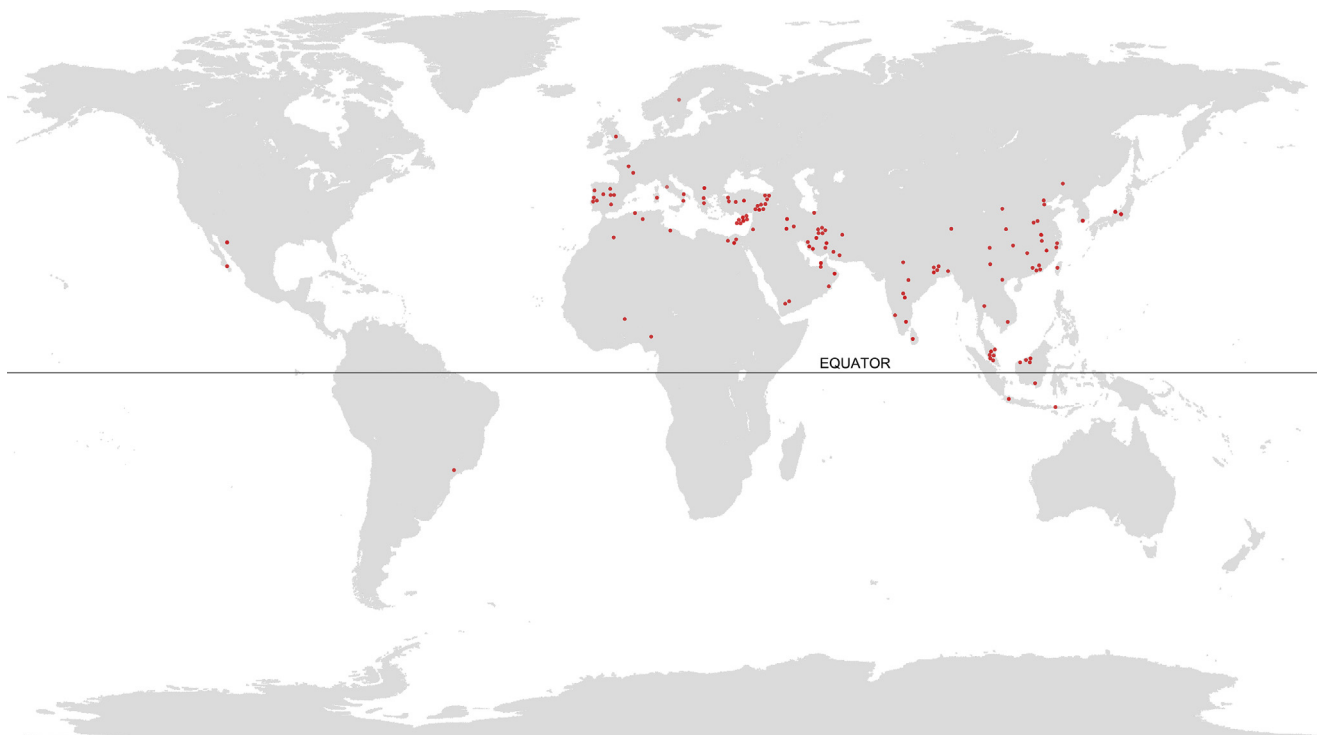
vernacular architecture was represented by a red dot in the map. Nowadays, China and Iran have emerged as research centers on vernacular architecture, followed by Malaysia, Turkey and India. This map also shows that many large areas of the world still lack research on vernacular architecture. Specifically, these regions are: Russia, Central Asia, a large part of Africa, Australia and the whole of most of North and South America. These gaps do not reflect the fact that these regions are rich in vernacular architectural heritage (Wikipedia contributors, 2018; Natural Homes, 2018). It is plausible that the capacity of scientific research in these regions is not responsible for these gaps. Therefore, we expect that one result of the present study is to promote research in these regions, thereby contributing knowledge to the scope and differentiation of world vernacular architecture.

Fig. 7 details the number of publications of top 10 countries derived from Fig. 6. The top five all come from in Asia while the remaining countries locate around the Mediterranean Sea. The positions around the Tropic of Cancer and the equator is a hint of a common characteristic that the climate of these countries have a warm/hot season each year. This raises a concern about whether there exists a correlation between the climate types and the number of studies on vernacular architecture. Climate is an important factor shaping the architectural patterns in each geographic area. We are interested in the climatic factors in the collected studies (listed in Fig. 8). It can be seen that architecture in hot, warm and humid climates was intensively investigated in many studies,

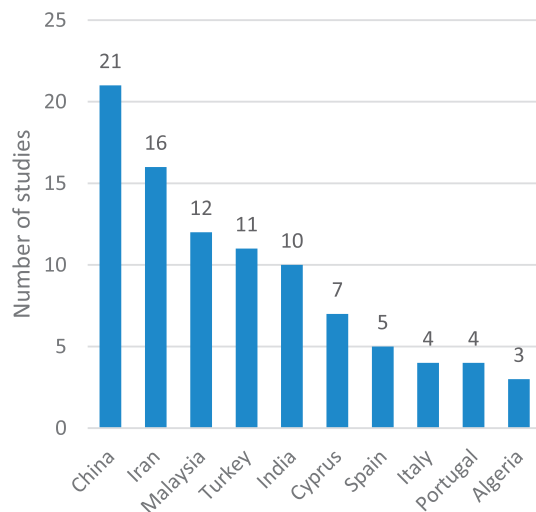
while studies for cold climates are quite meager. The three most studied climatic zones typically have a hot weather period (year-round or in summer). This result indicates that indigenous architecture in cold climates (e.g.  $C_{sb}$ ,  $C_{wb}$ ,  $C_{fb}$ ,  $D_{fb}$ ,  $D_{fc}$ ) should be further studied and published. We assume that the hot climate seems to pose many challenges to the role of architecture in regulating the indoor microclimate, such as the need to provide proper shading and ventilation, and so it receives greater attention than the cold climate.

### 3.2. The research objectives of studies on vernacular architecture

The major research objectives of the collected studies were examined and categorized as shown in the Supplementary data. Table 1 lists the research objectives found and their corresponding percentage in order from highest to lowest. Overlapping between some research objectives may occur due to the inconsistent interpretation and understanding between the scholars and the authors of this study. Since a study can have more than one objective, we have counted 152 objectives from 127 studies that we have collected. These objectives are categorized and classified into 15 major categories (see Table 1) which were established by examining all 152 objectives and grouping similar ones into the most appropriate category. By doing this, none of the objectives was omitted and each category will have at least one objective belonging to it.



**Fig. 6** World map showing a raw estimation of the distribution of the studies on vernacular architecture – until August 2018 (For the high-resolution image, please refer to the web version of this article).



**Fig. 7** Top ten countries in the number of publications on vernacular architecture.

From Table 1, the majority of the research (approx. 60%) defines objectives with a clear differentiation, indicating that studies on vernacular architecture mostly focus on passive/bioclimatic/environmental/ecological design principles/measures/features, and on assessing the environmental conditions inside the buildings. This result clearly shows a strong polarization of the goal of the studies, showing the top concern for the issue of sustainable design and for ensuring indoor conditions of vernacular buildings in the modern age. In addition, the cultural, social and

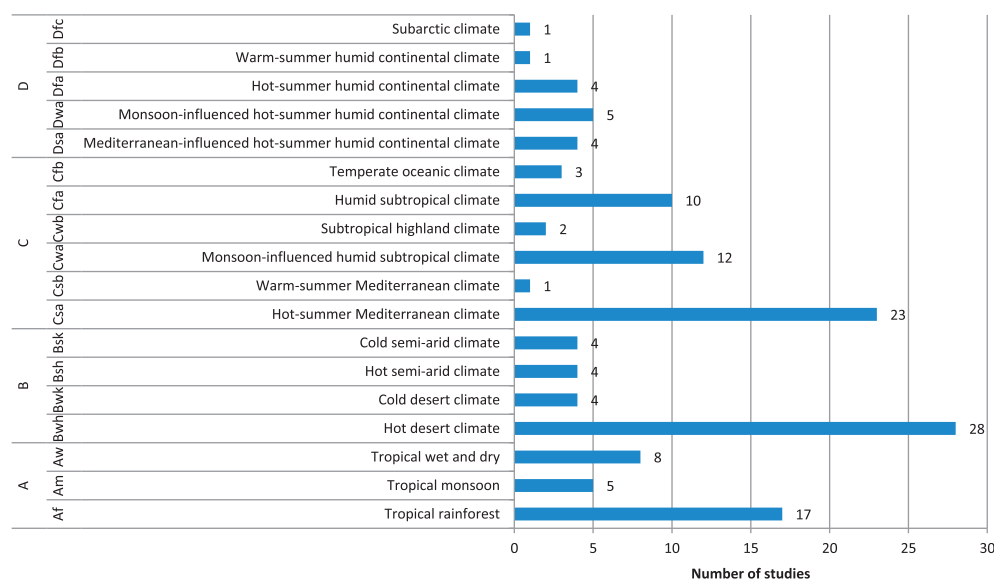
intellectual values embedded within this type of heritage are also attractive, accounting for nearly 20% of the total research objectives. Other research objectives do not receive too much attention.

The objective of the conservation of vernacular architecture is not set out as a primary aim in most of the studies. However, many studies did emphasize the importance of preserving and promoting the values embodied in vernacular architecture (Nguyen et al., 2011; Kamarudin, 2015; Barbero-Barrera et al., 2014). Such preservation is principally linked to the architectural, historical, and cultural values that vernacular architecture, along with its "ecosystem", represents.

This investigation found that most studies (nearly 86% of 127 studies) only focused on a unique research objective. However, some authors tried to resolve two objectives at the same time (Bekleyen et al., 1998; Martín et al., 2010; Prasetyo et al., 2014; Liu et al., 2017; Heidari et al., 2017). Particularly, even more than 2 research objectives were found in a few studies, for example: Yildiz and Manioğlu (2015) and Karabag and Fellahi (2017). Research objectives determine the scope, depth and the overall direction of a study and are linked directly to the research findings; however, some authors (Alp, 1991; Jingxia, 1996; Ozay, 2005) have not clarified their research objectives. Consequently, the results of these studies did not satisfy any specific goal or there is no clear direction for their research. This kind of omission should be avoided.

The concept "local context" - including the climate - is a decisive factor in creating architectural spaces, along with the influence of cultural aspects. Through this study, we





**Fig. 8** Distribution of the studies by climate types - according to the modified Köppen climate classification system (Beck et al., 2018).

found that most of the research objectives are to understand how vernacular architecture manages the relationship with the local climate, regardless of the type of climate which, for example may be hot and dry in the deserts, or cold and icy near the poles. However, we do not have enough data to assess the relationship between research objectives and climate types, and this opens up a new research opportunity.

### 3.3. Research objects in the selected studies

The research objects of the 127 studies were identified and listed as shown in the [Supplementary data](#). By categorizing this list, we observed that in most of the cases the authors focused only on one research object. In 98/127 studies (or 77.8%) vernacular/traditional houses (homes, dwellings, residential buildings) were the major focus of the scholars. In addition, 27 studies focused on generic vernacular buildings. Four others (Dhote et al., 2012; Philokyprou et al., 2013; Dayaratne, 2018; Kashani, 2013) investigate the urban fabric or the structure of vernacular settlements. The remaining one (Scatigno et al., 2016) studied the microclimate in an ancient *mithraeum*.

Vernacular architecture encompasses diverse manmade structures, including private homes, public buildings, religious structures, and forms and structures of urban settlements. The overwhelming proportion of housing studies shows that housing is the most popular and easily accessible vernacular focus, and one that can be found anywhere in the world. However, it can be seen that there are still many types of buildings which attract only a few studies, opening thereby new future research opportunities. Through this investigation, we suggest that public and religious buildings, and the urban form and space of vernacular heritages should obtain stronger attention from the architectural research community.

### 3.4. Research methods applied to vernacular architecture studies

#### 3.4.1. Classification of research methods in the selected studies

Research methodology is defined as the specific procedures or techniques used to identify, select, process, and analyze information about a topic. It is crucial because of its great influence on the overall validity and reliability of a study. Generally, a research method can be categorized into two principle classes: qualitative or quantitative methods, however some methods may lie somewhere between these two extremes, being considered as intermediate methods. In architecture, some scholars have carefully studied, identified, and categorized the research methods applied to architectural research. In the book entitled, "*Architectural research methods*", Groat and Wang (2013) comprehensively investigated and stated that there exist 7 dominant methods in architectural research (see [Table 2](#)). Mahgoub (2014) modified and expanded the work of Groat and Wang by suggesting two other methods, namely "theoretical research" and "action research". Another important update is on the relationship between design and research. In particular, it explores "research by design", that is, generating new knowledge using design as a method, as do a number of publications (Handa, 2017); among them are "*Design Innovation for the Built Environment: Research by Design and the Renovation of Practice*" edited by Hensel (2013), and "*Design Research in Architecture: An Overview*", edited by Fraser (2013). These works offer an emerging perspective that research by design has become a way to engage in the generation of new knowledge.

The research methods in the above-mentioned studies are summarized and briefly described in [Table 2](#). As shown in the [Supplementary data](#), this study verified the research methods used in each publication, described and

**Table 1** Share of the research objectives of the studies on vernacular architecture.

	Categories of the research objectives	Count (times)	Share (%)
1	To investigate passive/bioclimatic/environmental/ecological design principles/measures/features to achieve a comfortable living environment, eco-friendly and energy-efficient architecture;	52	34.2%
2	To evaluate indoor environmental conditions (occupants' comfort, temperature, humidity, wind, light ...);	37	24.3%
3	To investigate social – cultural values of vernacular architecture;	15	9.9%
4	To study ancient wisdom/knowledge embedded in vernacular architecture that can be applied to contemporary buildings;	14	9.2%
5	To study architectural styles and/or forms of vernacular architecture;	7	4.6%
6	To evaluate and/or detect conservation problems of vernacular architecture;	4	2.6%
7	To evaluate and/or compare performance of vernacular/traditional buildings in different climates or with contemporary counterparts;	4	2.6%
8	To draw attention to the conservation of vernacular architecture;	3	2.0%
9	To study the use and reuse of building materials and measures regarding waste reduction;	3	2.0%
10	To establish an archive of architectural documents on vernacular architecture;	3	2.0%
11	To study building physical phenomenon in ancient buildings;	3	2.0%
12	To study the perceptions and expectations of occupants in the buildings;	2	1.3%
13	To study architectural changes over time occurring in vernacular architecture;	2	1.3%
14	To learn about vernacular construction techniques;	2	1.3%
15	To test the implementation of modern systems (e.g. HVAC systems) in vernacular/traditional buildings;	1	0.7%
	Total	152	100.00%

categorized it, and finally the obtained data was analyzed (see Fig. 9 and Fig. 10).

Fig. 9 reveals the use frequency of the research methods mentioned in Table 2, showing a clear stratification among the methods. The most used methods are experimental research, simulation research (quantitative methods), interpretative research, and qualitative research (qualitative methods). Some studies employed case study methods, combined methods, and survey research methods (intermediate methods). The remaining methods were found in this investigation to be much less used. It can be seen that the use frequency of both qualitative methods and quantitative methods were rather similar, indicating their equal importance in these studies.

We investigated the number of methods employed in each of the 127 studies. The investigation returned a surprising result that many studies (54/127 studies, or 42.5%) combined two, or more than two research methods. Exceptionally, [Gabril \(2014\)](#) employed up to four methods to study vernacular architecture in Libya. We also observed that most authors tend to combine a qualitative method with a quantitative one with an aim of strengthening the validity and reliability of the research results.

### 3.4.2. Trends in selecting the research methods over time

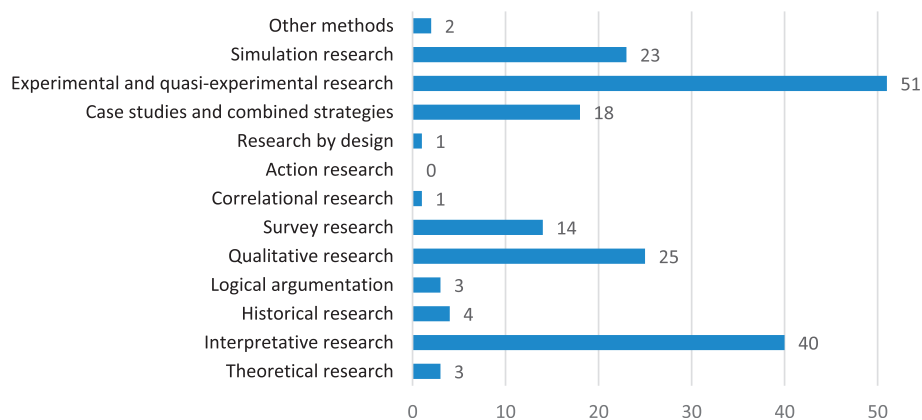
Within our survey sample, we divided the studies into two groups based on their publication year, corresponding to two periods: from 1986 to 2010 and from 2011 to present. The year 2010 was used as a split point because it divides

the sample (127 studies) into two smaller ones which are large enough to conduct the analysis (35 vs 92 studies). The year 2000 sounds more reasonable, but it was not selected because there were only 9 studies in the period 1986–2000. In each period, the share of the research methods was presented using a pie chart. Fig. 10 shows and compares the share of the research methods in these two periods. The share of each method was sorted from the smallest to the largest. The comparison indicates that there has been a considerable increase in use rate of quantitative methods since 2010 (e.g., experimental and simulation research). This corresponds to a significant reduction in the popularity of qualitative methods (e.g., interpretative or qualitative research). The share of simulation research has sharply increased, from 6.7% to 14.4% whereas experimental and quasi-experimental research has slightly increased (less than 1%) during the same period, indicating that scholars tend to choose simulations as their quantitative research tools.

Table 3 compares the use percentage of the categories of research methods in the two periods 1986–2010 and 2011 to present. The categories “qualitative – intermediate - quantitative methods, others” have already been introduced in Table 2. Their percentages were calculated by using the data in Fig. 10. Table 3 shows that there was a shift from qualitative research methods (low reliability) towards quantitative research methods (with higher reliability). The use rate of qualitative methods decreased by 16.6% in the period 2011 to present while an increased use rate of the quantitative methods of 8.4% was observed in

**Table 2** A summary of research methods applied to studies in architecture.

Type	Mahgoub (2014)	Groat and Wang (2013)	Hensel (2013) + Fraser (2013)	Description or examples -revised and expanded from Mahgoub (2014).
Qualitative methods	Theoretical research			Design optimization algorithms, mathematical theories.
	Interpretative research	Historical research		Examining past events to draw conclusions and make predictions about the future, e.g., theories of architectural history.
		Logical argumentation		The science that is used to explain or represent a consistent argument about a particular topic.
Intermediate methods	Qualitative research	Qualitative research		Participant (or field) observation.
	Survey research	Correlational research		Encompassing any measurement procedures that involve asking questions of respondents and analyzing obtained information.
	Action research		Research by design	Demonstration projects, advocacy planning.
Quantitative methods		Case studies and combined strategies		A particular instance of something used or analyzed in order to illustrate a thesis or principle.
	Experimental research	Experimental and quasi-experimental research		A scientific process used to actively influence something to observe the consequences, i.e. material testing.
	Simulation research	Simulation research		A model, or an imitation of the operation of a real-world process or system, i.e. gaming simulation, computer simulation.
Other methods				Hybrid methods, ICT (e.g., information and communication technology) method, archival research method).

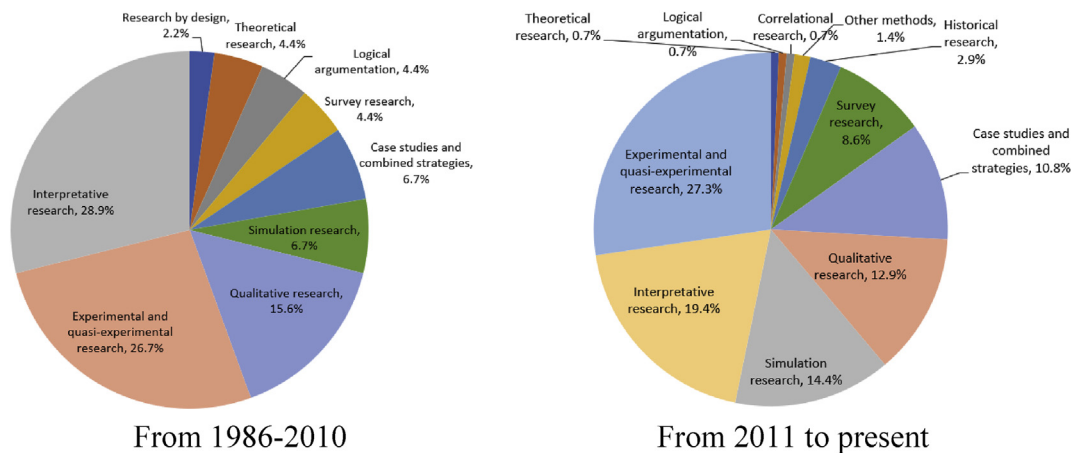
**Fig. 9** Use frequency of the research methods applied to studies on vernacular architecture.

the same period. The significant progress of digital experimental facilities, computer simulation programs, and the increasing quality requirements of scientific publishers may be the main cause of this shift. We also observed a similar increased trend of the number of building optimization studies using simulation programs in recent years (Nguyen et al., 2014).

We continued to question the relationship between the research topics and the research methods and how they influence the quality of the studies. First, we supposed that the citation metric is a good measure of quality of a

scientific research. The average number of citations of an article in the field engineering and technology in the period 1990–2010 was estimated at around 13, as given by Marx and Bornmann (2015). Among 127 studies in the sample, through an exhaustive search from Google Scholar, we found 63 studies having 13 or more citations. These 63 studies create a new sample of highly cited articles on vernacular architecture. Fig. 11 shows the share of research methods which were used in these 63 studies. The share continues to show the higher use rate of the quantitative research methods (see Fig. 12).





**Fig. 10** Share of the research methods and its changes over time (Note: The research methods were used 45 times in 35 studies of the period 1986–2010. Similarly, these were used 139 times in 92 studies of the period 2011 to present).

**Table 3** Share of the research methods by categories.

	From 1986 to 2010	From 2011 to present
Qualitative methods	53.3%	36.7%
Intermediate methods	13.3%	20.1%
Quantitative methods	33.3%	41.7%
Others	0%	1.4%

that the experimental and quasi-experimental research is the most persuasive method in studying vernacular architecture.

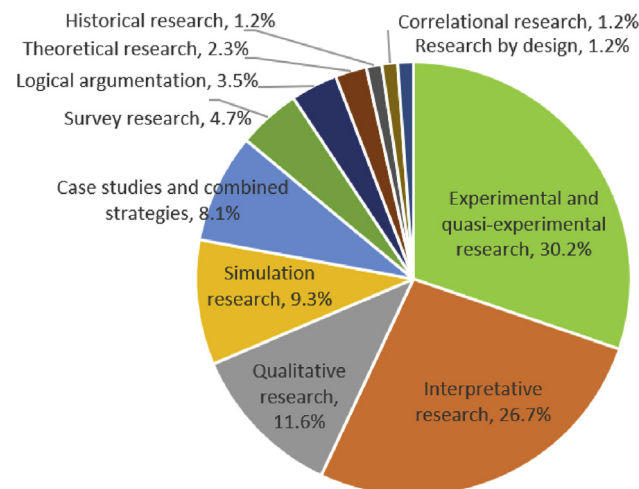
Another interesting finding is that there is a clear relationship between research methods and research objectives. All the research objectives of 11/13 studies using the experimental method (in the top 20 highly cited articles) were to accurately evaluate the indoor environmental conditions and thermal comfort. It was also observed that the research objectives of this kind were often further reinforced by simulation results, which help to evaluate the research topic more comprehensively.

### 3.5. Important lessons derived from the findings of these studies

It is worthy of note that the findings from these studies covered a wide range of issues and their concluding remarks were not homogeneous. Vernacular architecture across the world offers a diverse panorama of human response to the natural environment, reflecting natural, cultural and social context of the varied sites; from the cold climate of Tibet (Zhang et al., 2017b) to the hot arid climate of Yazd (Keshtkaran, 2011), from hot humid South East Asia (Kamarudin, 2015), to cold and dry Scandinavia (Almssad and Almusaed, 2015). Therefore, it is not possible to draw a general conclusion for these studies. However, we observed some common themes in the conclusions from the many studies as reported below.

#### - Qualitative findings:

+ Most studies cited in this paper favorably appreciate the environmental sustainability of vernacular architecture through its evolution of construction techniques, use of resources, passive building operation, and ecological lifestyle of building occupants. Vernacular architecture provides a healthy shelter for many generations of people, but it still guarantees the principles of sustainable development. This fact has become more and more important in promoting a sustainable future of



**Fig. 11** Share of the research methods in the top 63 highly cited articles on vernacular architecture.

Taking a closer look, it was found that robust quantitative methods, such as experiment or simulation, tend to help studies to be more appreciated, indicated by the high citation rates. Among 10 top highly cited articles, experimental and quasi-experimental research was found 7 times. Similarly, 13 studies in the top 20 highly cited articles used this method. Only 5/20 articles of the top 20 used the interpretative method. These findings indicate



**Fig. 12** A visual dialogue between traditional design elements and contemporary architecture. The Termitary house in Vietnam (left) inherits the spirit of the vernacular porous adobe brick wall; and new Qatar University (right) “breathes” in the way that traditional buildings in the region operated with windcatchers

the built environment, as stressed by (Tomovska and Radivojević, 2017; Keskin and Erbay, 2016).

+ Many scholars have affirmed the social, cultural, and heritage values of vernacular architecture that are important and need to be protected and preserved in order to maintain the diversity of the culture of each region/country and the whole of humankind (Ghaffarian and Dahlan, 2012; Bekleyen et al., 1998).

+ Vernacular architecture in some regions has special architectural styles and/or expression of artistic values (Ghaffarian and Dahlan, 2012; Osasona, 2007), or is generated under stringent design rules (Chiou and Krishnamurti, 1995). Many contemporary designs are inspired by vernacular/traditional forms in which social, cultural, spatial, physical, technological, and aesthetic factors are combined into one complex entity. Some examples were described by Rashid and Ara (2015).

+ Many design solutions and building characteristics of vernacular architecture are considered, evaluated and recommended for contemporary development in order to enhance environmental sustainability of the current built environment (Dayaratne, 2018; Hatamipour and Abedi, 2008; Soflaei et al., 2017; Foruzanmehr, 2015).

#### - Quantitative findings:

+ On the indoor conditions:

- Through survey and analysis, thermal comfort preferences of building occupants (Zhang et al., 2018; Singh et al., 2010) and comfort equations (Gabril, 2014) were derived from the studies.
- As mentioned in the previous section, a large number of studies put effort to explain the indoor environmental conditions of vernacular architecture. Through quantitative research methods, many of the studies have proved that vernacular architecture was able to

provide comfortable/acceptable and stable indoor environmental conditions during most of its life span (Singh et al., 2010; Priya et al., 2012; Samuel et al., 2017; Dili et al., 2010) and has lower energy consumption compared with modern houses (Cantin et al., 2010).

- A few studies indicated that the indoor microclimate of vernacular buildings are not always thermally comfortable, especially in extreme weather (e.g. very hot summer or cold winter) (Prasetyo et al., 2014; Nguyen et al., 2011; Nguyen, 2013; Gou et al., 2015; Huang et al., 2017a,b; Ooka, 2002); some others stated that the indoor microclimate was damp, and relative humidity was higher than outdoors due to the low temperature and high humidity ratio which may cause visible mold (Huang et al., 2017a; Zhang et al., 2017a; Karyono et al., 2012) cites several conservation problems, e.g. biological growth and visible efflorescence salts (Scatigno et al., 2016). It is suggested that the use of hygroscopic materials is a passive way to moderate indoor humidity levels. The material that adsorbs and desorbs water vapor can be used to moderate the amplitude of indoor relative humidity and therefore to participate in the improvement of the hygrothermal performance and indoor air quality (Shea et al., 2012; Tran-Le et al., 2018).

+ On the comparison of thermal performance of the vernacular houses: The results given by Martín et al. (2010) show better indoor conditions in the traditional houses than the modern houses thanks to the effect of high thermal inertia. Similar findings were obtained in the study in Oman (Majid et al., 2012). In terms of humidity, Huang et al. (2017a) found that average relative

humidity in the investigated vernacular dwelling (over 83%) was higher than that (around 75%) in the modern dwelling. [Fan and Chen \(2016\)](#) also found that cave dwellings have a better thermal environment, compared with other housing types.

+ On the phenomenon of heat transfer in ancient buildings: [Al-Motawakel et al. \(1986\)](#) used a mathematical heat transfer model to study the performance of wall types and proposed the most suitable one for the local climate. [Shi et al. \(2012\)](#) proposed to use foam concrete to fill in cavity walls to increase thermal resistance by 24%. [Scatigno et al. \(2016\)](#) carefully investigated the indoor environment of a particular *Mithraeum* in Rome, identifying the critical areas where the building components are mostly at risk.

Actually, there are many other results discovered in the studies, however these results were not representative or have not been confirmed by similar findings, so we do not mention them in this section.

### 3.6. Challenges and trends in the studies on vernacular architecture

Most researchers agree that vernacular architecture is a proven model of sustainable architecture, regarding both environmental, economic and social aspects. However, the contemporary building industry shows that buildings designed and constructed by modern technology are still the overwhelming norm. Vernacular architecture is increasingly damaged and gradually lost. Many regions have introduced tighter building standards and zoning regulations (e.g., fire safety, building life expectancy, energy codes), which make vernacular techniques difficult or impossible to apply.

The benefits of vernacular architecture have been recognized throughout most of the long human history, but have narrowed in the modern period; however, they are now returning and influencing sustainable building design. Despite some challenges, the adaptation of models obtained from vernacular architecture have gained in interest among some contemporary designers. There have been a lot of efforts to realize this idea, as seen in [Fig. 11](#). Many studies in this paper have shown that it is not possible to use vernacular architectural models in a stereotyped manner in modern society. However, anything learned from indigenous architecture is very valuable, providing an important link between people and the environment. It helps identify the unique characteristics of people, places, cultures, and climates. It forces us to think how to establish a community of pure survival and to minimize our need.

Vernacular architecture was created to operate completely passively. However, a few studies have shown that in some cases vernacular architecture was not able to provide a comfortable environment under extreme weather ([Prasetyo et al., 2014](#); [Nguyen et al., 2011](#); [Nguyen, 2013](#); [Gou et al., 2015](#); [Huang et al., 2017b](#); [Ooka, 2002](#)). This raises the question of how to mitigate the remaining discomfort in the vernacular structures, and to satisfy contemporary human thermal comfort standards. Vernacular structures show a climate-friendly approach to local

dwellings and a natural and resource conscious solution for housing needs for different areas of the earth. In order to progress sustainable architecture and buildings in the future, designers must first have knowledge of the past and use these strategies as a well-balanced approach to achieve optimal environmental efficiency. We expect that there will be more and more studies to realize the benefit of the application of vernacular wisdom into modern architectural design.

Through this study, we also found that the following trends in the research on vernacular architecture need to be strengthened:

- To promote studies in the regions that still lack information, e.g., in Africa, South America, Russia, Central Asia, and Australia.
- To provide a stronger theoretical and practical basis for effectively preserving the values of vernacular heritage and protecting the ancient building stock.
- To investigate the perception and expectation of occupants living in existing vernacular architecture.
- To study whether modern systems can be implemented in old vernacular buildings, thereby meeting present living standards without changing their original/traditional forms and/or features.

Vernacular architecture, such as the igloos of the Inuit people, or Tuareg tents - the folk structures evolved over thousands of years - allow people to survive easily in the most severe climate conditions on earth. They are examples showing that vernacular architecture is the product of building cultures - a complex system of people, relationships, beliefs, aesthetic styles, construction techniques, and habits in which design and buildings are combined. Therefore, it is essential to encourage new approaches to vernacular architecture that go beyond the perspective of architects alone, to promote the emergence of an improved built environment. For example, Christopher Alexander and his partners ([1977](#)) attempted to identify adaptive characteristics of traditional architecture that were applied across cultures. This novel idea simply comes from the observation that most of the wonderful places of the world were not made by architects, but by the local people.

## 4. Summary and conclusion

Vernacular architecture – a highly flexible and reasonable way to address human needs - seems to be largely forgotten in contemporary architecture. Nevertheless, due to the increasing pressure of recent global environmental problems, this trend has shifted logically in another way. Architects are embracing regionalism and the tradition evidenced in the ancient structures, arguing that these structures have been proven to be energy efficient and highly sustainable. In the era of rapid technological development and massive construction, there is still much to learn from the cumulative knowledge embedded in traditional structures. The low-tech methods used in vernacular architecture can be used to create buildings and environments well-suited to local climate and culture. This is in



contrast to the design of many modern buildings that do not take local conditions into account.

The rapidly increasing number of vernacular architecture studies in the last three decades has demonstrated a great interest by the building research community on this issue, and this is a trend that is likely to continue in the coming years. This increased trend was clearly observed in Asia and Europe. Motivations of this movement may include the advances in computational modeling, and the need to respond to more stringent design requirements of sustainable buildings, including green building rating systems.

This paper examines a set of samples of 127 studies on vernacular architecture from which evaluations, assessments and orientations have been drawn. The results show an uneven geographic and climatic distribution of the studies. China, Iran, Malaysia, Turkey and India have emerged as research center of vernacular architecture while Russia, Central Asia, Africa, America, and Australia still lack studies. It was observed that the number of studies on vernacular architecture in warm and hot climates is much higher than that of the cold climates. Architecture in cold climates (e.g.  $C_{sb}$ ,  $C_{wb}$ ,  $C_{fb}$ ,  $D_{fb}$ ,  $D_{fc}$ ) should be further studied and reported. About 60% of the 127 studies focus on sustainable features, and on assessing the environmental conditions inside vernacular architecture. The cultural, social, and intellectual values embedded within this type of heritage attracted nearly 20% of the studies. Other topics do not receive significant attention, occupying the 20% remaining. Vernacular houses/dwellings/residential buildings were the top research objects, accounting for 77.8% of the studies while other vernacular structures did not gain much attention. The investigation found that the experimental research and interpretative research were the top two most used methods. Since 2011, there has been a clear shift towards quantitative research methods as its use rate increased by 8.4%, with a decreased use rate of qualitative research of 16.6% in the same period, compared with those of the period 1986–2010. Generic findings from the sample set were also reported and analyzed. These findings clearly offer significant reference values for other studies. Challenges are still ahead, but the authors strongly believe that the lessons from vernacular architecture will soon become a useful input within contemporary building design and construction.

The lessons from vernacular architecture across the world have emphasized the importance of a climate conscious approach to building design to accomplish human comfort without excessive use of natural resources. At the same time, vernacular architecture is argued to retain many social, cultural, and heritage values within the communities. The studies suggest that vernacular architecture offers robust evidence that humans can live in harmony with nature, confirming the need to preserve its values for future generations.

Finally, it is expected that these survey results will support diverse inquiries about vernacular architecture around the world and be used as a resource and an orientation to support numerous subsequent publications by varied authors.

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## Appendix A. Supplementary data

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