Assessment of the Bioclimatic Elements of Vernacular Architecture. The Historic Centre of Nicosia, Cyprus

Maria PHILOKYPROU(1), Aimilios MICHAEL(2), Stavroula THRIVALOU(3)
(1) Department of Architecture, School of Engineering, University of Cyprus, Nicosia, Cyprus
mphiloky@ucy.ac.cy, (2) amilios@ucy.ac.cy, (3)stralou@gmail.com

Abstract
The present study addresses the identification of the factors and elements that contribute to the improvement of thermal comfort within traditional buildings and their built environment. This investigation is part of an ongoing research programme that is funded by the Republic of Cyprus and the European Regional Development Fund (through the Research Promotion Foundation) regarding the vernacular architecture of Cyprus that includes in situ measurements of temperature and humidity using data loggers and weather stations. Two areas of the historic centre of Nicosia, which have preserved their original character, were selected for the study. After an overall historic and architectural investigation of these areas through historic documentation and survey maps, a study of a large number of buildings from a typological, bioclimatic and construction material point of view has been carried out. The bioclimatic strategies of heating, cooling and microclimatic conditions were studied in detail. This preliminary research showed the various environmental features of vernacular architecture (central yards, semi-open spaces, construction and materiality etc.). The research aims at establishing a bioclimatically-based approach in the conservation of traditional buildings and thus contributing to the regeneration and sustainable development of the urban environment of such a solid traditional historic core as that of the Walled City of Nicosia.

Keywords: vernacular, bioclimatic, traditional construction, courtyards, semi-open spaces

1. Introduction
Vernacular architecture, which incorporates rural settlements as well as urban historic centres, has always constituted an important part of the cultural heritage of every country. Traditional dwellings are considered by definition sustainable, incorporating many features friendly to the environment (use of local materials, adaptation to the landscape, central yards, arrangement of open and semi-open spaces etc.). The identification, protection and preservation of these features in the rapidly changing context of contemporary cities is imperative in order to maintain the values linked to sustainability. A “BioVernacular” research project (ΑΝΘΡΩΠΙΣΤΙΚΕΣ ΑΝΘΡΩΠΟ/0609/BIE) is currently underway in the aforementioned domain. It is funded by the Republic of Cyprus and the European Regional Development Fund (through Cyprus Research Promotion Foundation’s Framework Programme for Research, Technological Development and Innovation Δέκαν 2009-2010) and was initiated in July 2012 in the historic centre of Nicosia in Cyprus with the selection and detailed analysis of two neighbourhoods in the historic core, using typological, architectural and structural criteria. The project incorporates the following goals: identification of the bioclimatic elements encountered; monitoring of temperature and relative humidity levels in a selected number of dwellings; definition of the bioclimatic and microclimatic conditions that affect thermal comfort; simulation of the energy efficiency of a selected sample of buildings; calculation on an hourly basis of thermal and cooling loads; drafting of technical guidance and proposals for traditional buildings and measures so as to improve bioclimatic features and comfort conditions within the building envelope.

This paper presents some qualitative findings of the project regarding the identified environmental design elements in the built heritage of Nicosia. The observations refer to the urban tissue as well as the vernacular dwellings. The paper aims at identifying and documenting the bioclimatic
characteristics of traditional dwellings in the Walled City of Nicosia and their immediate built environment which is essential for enhancing an environmentally-friendly approach in the rehabilitation process.

2. The methodology
The methodology used in the initial part of the research project refers to the preliminary qualitative analysis, diagnosis and assessment of the bioclimatic elements of the urban tissue and vernacular dwellings of Nicosia. The main objective is to confirm all the individual factors that constitute the so-called “environmental approach in vernacular architecture” through scientific and systematic investigation.

Initially an in-depth research through historic documentation which provided insight into various historic, ethnic and social factors that contributed to a series of events such as the setting of the city in a specific location and the relation to the evolution of the built environment was conducted. The reinterpretation of the urban evolution and examination of the interrelated structural and morphological components provides significant information with regard to the origin of elements such as the urban tissue and form, the types of buildings and their architectural characteristics that may embrace an environmental essence.

Another important tool of great significance is the study of survey maps of various periods. The relative information, derived from the study of the maps, refers to: “the area and city level”, “the urban tissue level” and the “building types level”. With regard to the “area and the city level” the information refers to macroclimatic conditions, geomorphological and landscape qualities, city shape and form. With reference to the “urban tissue level”, the orientation of the streets, shading and sunlight provisions, ventilation and cooling factors as well as urban vegetation and quality of open and semi-open spaces are investigated. Under the “building types level”, the typology in terms of arrangement of spaces (courtyards etc), the building materials and techniques and the cooling and heating strategies and use of local resources such as water are examined.

At this stage of investigation, a field study is of great significance. It provides updated information on the fusion of civil components and the historic stratification. Furthermore, the personal communication with the residents, the actual users of the vernacular dwellings and the city form, enhances evaluation of the comfort offered by the specific urban tissue and the individual buildings. The wide variation between objective and subjective sense of comfort, the residences’ observations, opinions and experiences are a valuable tool in both the comprehension of the bioclimatic function of the houses as well as the evaluation of its contribution to the achievement of comfort.

Concluding this part of the research, the findings are presented according to the scale they apply: beginning with the territory and city level (location, geomorphology, limitations of topography), moving on to the urban tissue level and the scale of the neighborhood (urban development), and focusing on the building level and the applied bioclimatic strategies (cooling, heating and microclimatic environment strategies).

3. Territory and city level. Evaluation of environmental elements
Initially, the main parameters for the location of the city of Nicosia were examined with the aim of commenting on the suitability of such a location from the environmental point of view. The location of Nicosia in the central area of the island, in a fertile plain, between two mountain ranges and the spring torrent that crossed it played an important role in the creation of its climatic conditions.

A main characteristic of the Mesaoria plain as well as of the whole island is the large fluctuation between the highest temperature during day and the lowest temperature during night (being between 8-10°C during the winter, and 16°C during the summer in the plains). The sunshine during the summer has a duration of about 11.5 hours and during the winter 5.5 hours. The prevailing winds during the winter are southwest and east, during the summer west and north and during the spring and the fall west and northeast [1]. The relative humidity level, due to underground water sources, is another factor to be considered. The city elevation and the distance from the seaside play an important role in the amount of relative humidity in the air. During the days in winter and the nights throughout the year the relative humidity varies between 65-95%. At noon during the summer the relative humidity becomes very low to a level of 30% [1].

It is quite evident that the location of Nicosia has been crucial for the city’s evolution. The Pedieos river has played a vital role in Nicosia’s setting and development [2]. Even though it is practically a spring torrent, the Pedieos has nevertheless sustained human settlements in its vicinity for thousands of years. Nicosia has been inhabited without an interruption since at least the Chalcolithic period (4000 BC), but it was not until the 11th century, in the Lusignan Times, that Nicosia became the capital of the island [3]. Under the pressure imposed by the Arab raids on the island, which eventually resulted in the abandonment of the coastal towns [4, 5], the administrative centre was moved to the interior of the island. The location of the ancient “Ledra” (Nicosia), being at the central crossing point of the commercial routes, offered comparative advantages for the new settlement [5].
From a geomorphological point of view, Nicosia lies in the middle of the island’s two largest plains (the Mesaoria in the East and Morphou plain on the West), at the foothills of the two mountain ranges. Troodos Mountain lies in the South, at a distance that prevents it from being considered as a physical obstacle causing obscurcation and shading. However, the range of Pentadaktylos Mountain extending on the north side prevents the wind descending from that direction in the summer period. As a result, a summer day is noticeably hot and dry, while at night north-westerly wind accesses and cools the area. The winter is moderate and rather rainy [1].

As far as the city form is concerned, there were a few limitations posed by the topography; the river bed and the rather moderately low hills in the vicinity. The importance of the Pedieos river in the formation of the built environment of Nicosia was great; it crossed the whole walled city, transporting water and other materials (clay and marls from Troodos Mountain) and divided the city into two areas (north and south) connected with bridges. When the Venetians began to build new surrounding walls of the city in fear of Ottoman attack, the route of the river was diverted so as not to pass through the city; a route which is followed even now. With the primal criterion of the defence of the city the fortification wall formed with the 11 bastions defined the size of the city incorporating the aesthetic idea of the renaissance “citaedeal” [3].

Concluding on the evaluation of the environmental parameters incorporated in the design of the city, as far as the location of the settlement is concerned, despite defensive and financial issues, the location offered comparative advantages. The presence of crucial and vital sources, such as the river and the fertile land of the plain providing arable land and necessary building materials were decisive. The limitation of the location is the insufficient ventilation in the summer due to the mountain in the north. Consequently, vernacular architecture in such a location is called upon to respond to the favorable winter and rather unfavorable summer conditions, especially during the daytime (taking advantage of the winds and being protected from the direct sun radiation).

4. Urban and building level. Bioclimatic design parameters

4.1 Urban Evolution. Typology

Nicosia began its development by following the type of rural development of the settlements in the plains with houses occupying a large area and adapted harmonically with the surrounding geomorphology and the climatic conditions. Gradually the urban development of Nicosia was directed towards a more compact character with houses occupying a smaller area and adapted mainly to the street network [4,6].

According to the study of Demi Danilo [4], the first building type adopted in Nicosia was the so-called “domus” or “rural courtyard house”, built in the most elementary form of a single-storey building inside a fenced area used as a farmyard or orchard. The entrance was achieved through the courtyard from where access to the living areas of the house took place. The area occupied by the building in the plot varied in relation to the road access and the plot orientation, while the courtyard was always south orientated [1,4]. In order to protect the doors and windows of the main living areas from the rather uncomfortable summer sun, a kind of semi-open space (covered area) was developed along the south side of the building, locally referred to as “iliakos” based on the Greek word “ilies” (sun) [6,7]. This element was clearly incorporated into the building shell with the purpose of providing shelter from the climatic conditions, thus its bioclimatic function cannot be argued. Due to its size (3m in depth) it provided shading in the summertime when the sun was almost perpendicular, and allowed the sun to enter the living areas in the wintertime when the sun was lower.

With the development of the city, the increase of its population and prestige, the house gradually acquires more urban characteristics while the road allocation adjusts to a more urban dimension. The Byzantine “domus” presents a significant increase in the number of the original cells, capable of filling the entire plot area and facing the road, yet allowing an empty space for entrance, which was always achieved through the courtyard and never directly into the main living areas. In the cases of north south allotment the entrance was soon covered by a roof joined with the roof of the “iliakos”, irrespective of the position of the entrance; it was always extended so as to protect the entire southern facade of the building [4]. It is worth mentioning that in cases of east-west oriented roads the expansion was notable, increasing in this way the south-facing elevation and the corresponding area of “iliakos” (figure 1: B7). In the cases of north-south oriented roads, the buildings were located on the northern side of their plots, enlarged by filling the whole of that side [4]. The courtyard in this way remained south orientated, excluding obstructions and shading from neighbouring buildings. Consequently, in all plot cases the criterion for choosing the direction of the extension was purely climatic; the preference for a south orientation and direct solar gains is evident.

Another element of great importance that became remarkably widespread and eventually constituted one of the most important components of Nicosia's development in the 19th and the early 20th century is the appearance of special function buildings such as shops, inserted into the house courtyard fence as an independent space with direct contact with the road and access from it. In some variations, depending on the size of the plot, this individual function occupied the space between the covered
entrance area and the fence (figure 1: B2, A3). The resulting shape was the articulation of the main living areas alongside the road and the creation of a central covered entrance hall called a “portico” with lateral rooms opening into the yard and covered by a roof [4, 6] (figure 1: B3, A4, figure 2).

During the Lusignan Times intense urbanisation and increasing population within a limited available area initiated a process of land fragmentation using “cul de sac” type roads which are actually branches from the road, providing access to the inner core of the plots. The plots themselves were subdivided by an irregular tissue, embedded smaller and simpler variations of the courtyard house, while at the same time, some streets became wider. Serial allotments along the main axis appeared along with the urban mansions, prevailing in architecture design and height [4, 6]. The first extension of the original courtyard made by filling the side facing the road, was followed by a supplementary extension: i.e. the addition of a floor and a relevant loggia to protect the south façade or the addition of an extra room to one or both short sides of the plot which resulted in the typology of “L” (figure 1: B8, A5, A7) or “C” (figure 1: B5, B9). The access to the first floor was achieved mostly by an open-air linear staircase. The side facing the street beside the main entrance had small square windows at a considerable height above street level for security reasons [6] while the first floor windows were sometimes arched but considerably larger [4]. Actually, it was not until the Ottoman Rule that the urban tissue and the building types changed considerably; serial allotments along the main routes were largely increased by further land fragmentation using the “cul de sac” roads. The direct contact with the road became the prime criterion for the location of the building in the plot and more than any other variation; the “L” shaped arrangement became the most popular form for urban life [6]. Within a few decades after the arrival of the British in the late 19th century, the tissue was definitely completed by filling up all the empty areas. The traditional courtyard house was replaced by a “serial type” building which contained all the house functions within a smaller area; in this case, the central entrance door provided direct access to the central room and the yard acquired a decreasing size and importance (figure 3). The windows on the street front appeared at a lower level and acquired a larger size due to the change of social life (feeling of security).

Looking at the 1920s and 1930s, many variations of the “serial type” house appeared [4] and a new development was created: the “new courtyard house” (figure 4) as a combination of shapes and concepts of the two previous types (the position of the building facing the street-front and the courtyard type house looking into the yard in the back side). Consequently, the environmental criterion of the best orientation was left behind under the new development of the urban tissue and the necessity of direct contact with the street. In contrary to the above, the importance and the use of the semi-open spaces prevailed, being attached to the custom of living in the open air, which is actually a cultural expression related to the mild Mediterranean climate. It is notable that all the semi-open spaces are situated at the back of the house, leaving a plain frontage, as the social life of the family took place in the inner courtyard due to the introverted character of the society.

Fig. 1: Evolution of the original courtyard house - interpretation from reference [4]
The following map (figure 5) graphically presents all kinds of semi-open spaces encountered in the south part of the Walled City of Nicosia; it includes the semi-open areas described in the typology report as a main entrance to the courtyard or as a shelter in the form of loggia or “iliakos”. Partially covered alleys on the first floor are also marked. The map does not necessarily represent an accurate present situation because “porticos” were originally considered as semi-open spaces. However, at the present time many “porticos” are more likely to be closed, becoming part of the main internal living areas. Concluding on the number of semi-open spaces, it is evident that they are widespread; even denser in residential cores such as Ayios Antonios neighbourhood in the southwest and Chrysaliniotisa and Ayios Kasianos in the west. As far as the main direction of the spaces illustrated on the map, it is pointed out that, in accordance with the typology report, the “portico” as a main entrance space is perpendicular to the street, marking the entrance to the house. When the semi-open spaces are arranged in other directions or locations they can be considered as shelters serving as a protected transition from the internal to the external environment. The north-west quarter of the city, Chrysaliniotisa neighbourhood, offers a representative example of the evolution of the urban tissue where the presence of the “cul de sac” roads is recognizable and the dwellings preserve much of their original features. The map in figure 6 shows all the courtyards which appear in the Walled City of Nicosia, with various sizes thus underlining the introverted character of the social life. Figure 7 focuses on the neighbourhood of Chrysaliniotisa showing all courtyards and semi-open areas of the traditional buildings. All traditional dwellings incorporate a central yard and most of them have at least one semi-open space (more often a “portico” serving as an entrance to the houses). A number of dwellings incorporate a second semi-open space, an “iliakos” as an intermediate area between the separate rooms and the yard.

Through the study of the historic architectural evolution of the typology of Nicosia it is clear that some elements that remained and have been used during all periods are: the central yard at the back of the plot, the arrangement of spaces around the yard and the prevalence of semi-open spaces (used as entrances and shelters). These elements underline the aim of the residences to adapt their dwellings to the climatic conditions of the area (hot summer, mild winter, limited winds). The dwellings were frequently arranged in compact patterns, closely built with common walls, one attached to the other,
following the continuous urban system leaving small empty spaces in the form of public narrow streets and private courtyards. Thus, the vertical surfaces (walls) exposed to exterior environmental conditions are reduced and the thermal protection of the building envelope is increased. The shade between neighbouring buildings reduces the warming up of their walls by radiation. Thus, topography, geomorphology and climate are important parameters that play a significant role in the design.

**Fig. 5:** Semi-open spaces in the south part of the Walled City of Nicosia

**Fig. 6:** Open spaces in the south part of the Walled City of Nicosia
4.2 Building techniques and constructive materials

Besides the typology and the organisation of the traditional dwellings, building materials and techniques played a very important role in the design of vernacular architecture (morphology etc.). Descriptions of travellers visiting Nicosia in the late 19th century provide interesting information and perspectives of the city with regard to the urban morphology, the building materials used and the local architecture. In one such description Deschamps [8] stated: “Nicosia comprises a complex of mudbrick built houses with some stone constructions. Nicosia resembles a large village with narrow and winding streets. The newly built and quite presentable buildings do not constitute a separate neighbourhood but are to be found everywhere”.

As mentioned in the above extract and still evident at present, the materials used in the vernacular architecture are earth and stone which are to be found in abundance in the vicinity. The traditional dwellings constructed with earth and mudbricks, have stone foundations of local limestone, of Athalassa-Nicosia Formation called “Stone of Gerolakos”, [9] so as to protect the mudbrick walls from the rising damp. The building practice and techniques used are also described by several travellers. Louis Salvator [10] stated: “Building is carried out with great rapidity; some mortar composed of earth and straw, is poured from a mason’s tray with two handles over the mudbrick, another mudbrick is put on top, some more mortar is put on top of it, another brick and so on and the house is finished in almost no time. It also has the advantage of drying very soon after the process is finished”.

The financial aspect described, that is related with the cost of the construction and preservation, is also worth mentioning, as an indication of the value of each material according to its accessibility, cost of transportation and mechanical properties. According to Louis Salvator [10] “These houses (earth houses) are exceedingly cheap; a fine building costs hardly more than about half the price of the finest stone house in Nicosia. Houses made of mudbricks will last a hundred years, but they must be frequently repaired, as the plaster with straw with which the mud bricks are covered up will get rotten and leave holes in the wall.”

4.3 Bioclimatic strategies in traditional dwellings

The selection of appropriate building materials, apart from being partially imposed by availability, is also climatically driven. The suitable use of materials in the building’s envelope provides direct protection from the climatic conditions, while the materials of the buildings’ surroundings contribute to the development of desirable microclimatic conditions [11]. Thermal inertia secured by the thick mud brick and stone walls and the mass of the roof materials provide a small fluctuation in the internal temperatures [12]. The materiality of the floor surfaces, covered often with gypsum slabs, also affects the temperature of the immediate environment. Materials with high thermal inertia, such as stone,
were used in the open and semi-open spaces; their capacity to store heat and emit it with a delay, when the air temperature is lower, was appreciated and used [13].

Fig. 8: Bioclimatic design strategies in traditional dwellings in the historic centre of Nicosia, Cyprus.

With regard to the Mediterranean climate, vernacular architecture contributes during the entire year towards the bioclimatic strategies as follows: During the winter period improvement has been achieved by direct solar gains through the building envelope and the buildings openings (figure 8) and also by the protection against strong and cold winds. During the summer months the climatic conditions are improved by the reduction of the exposure to the solar radiation and the ensuring cross ventilation (figure 8) of the building envelope [12]. Cooling, heating and microclimatic environment strategies are described below in detail.

i) Cooling strategies
As mentioned before, vernacular architecture had to provide a climatically-responsive building model that could handle ventilation during the summer daytime, due to geomorphological limitations. Therefore, the building form had to offer as many ventilation possibilities as possible by combining night ventilation and cooling and at the same time being protected from the direct sunrays during hot summer days [13]. Suitable openings, frequently of small size, in the walls (figure 8) function as valves ensuring control of the air flow. Thus when they are closed during the winter they offer protection from the cold winter wind while when they are opened during the summertime they allow the circulation of cool air. The movement of the air through the building envelope depends greatly on the size, the shape and the position of the openings [13]. The small size openings on the façade on the streets (called “arseres”), located at a considerable height, were designed for the privacy of the domestic life [4]. Nevertheless their bioclimatic function cannot be disregarded. Due to the difference in temperature and density of the air, the hot air was forcibly extracted from the building envelope (stack effect) during the summer period (figure 9: C3, C4) [13]. The semi-open spaces (“iliakos” or “portico”) also enhance the air flow (figure 9: C5) especially due to the cross arrangement of the “portico”.

Another important cooling strategy is sunshading which protects the interior spaces from overheating during the summer period [13]. Shading covers, “iliakoi” and light pergolas with plants (in front of the south side of the buildings), solid plank or adjustable (movable) shutters (figure 9:C1, figure 8), roof overhangs, small or large balconies offer shading (figure 8, figure 9:C2) thus minimizing the direct sun radiation. In addition they favourably influence the natural lighting by reducing the reflection and offer protection from the rain.

Fig. 9: Bioclimatic design strategies of the traditional courtyard house during cooling period

ii) Heating strategies
Direct solar gains constitute the main strategy of bioclimatic design during the winter period (figure 10: H1). Such gains are derived from the south orientation of the building and its openings [13]. In cases where the south orientation is not an available option, indirect solar gains are derived from the building envelope, as solar radiation is captured through the walls and the roof (figure 10: H2). The elimination of heat losses also functions as protection from the strong cold winds (figure 7: H3).
iii) Strategies on the microclimatic environment

The existence of water elements in courtyards and in the surrounding areas of the buildings provides evaporation cooling which results in the decrease of the high temperatures during the summer (figure 11: E1). The watering of plants and the courtyard is a widely used technique that has prevailed as a traditional activity since the beginning of the last century for enhancing evaporation cooling. The relationship of the built and natural environment in addition to the improvement of the microclimatic and consequently the comfort conditions also provides a visual pleasure [11, 14].

Small scale central courtyards (figure 8, figure 11: E2) enhance the increase in temperature in relation to the larger open air spaces. This is desirable during winter as the floor materials (stones and/or earth) and the surrounding walls of the courtyard increase the urban heat effect. During the summer months the necessity of cooling such an area is imperative. In several cases the largest part of the courtyard is shaded from the surrounding building volumes and thus the temperature is kept at lower levels. External shading, especially with plants on pergolas (figure 11: E4), prevents the sunrays entering this area. Evaporation from green leaves causes cooling of the air which becomes heavier and falls down under the tree shadow, while the hot uprising air outside the house drives it through the archways and cross openings of the rooms, causing cool breezes in the interior spaces. During the summer nights the downlink nightly cooling air enters and is channeled through the rooms (through open windows and arches) because of the rising hot air outside the house and thus removes the heat stored in the rooms during the day. The combination of shading and the night cooling reduces the temperature keeping it at a level more close to thermal comfort in relation to the outside environment. The vegetation forms a naturally protected environment, which reduces the high temperatures during the summer period, shading the building envelope and reducing the sudden changes in humidity (figure 11: E3). Besides shading, vegetation can also prevent, filter or divert the air flow, thus affecting the internal ventilation of buildings (figure 11: E2). Evergreen as well as deciduous trees offer protection from a substantial amount of sun radiation, thus reducing the ground temperature. Shading provided by vegetation varies according to the kind of trees planted. Trees can also be used to prevent, filter and divert the air flow, thus influencing the ventilation of a building. It is worth noting that deciduous trees are usually planted in the south side of the buildings so that they allow the sun radiation onto the building during winter time. The planting of evergreen trees on the sides of the buildings affected by strong winds functions as a barrier to air flow and thus offers prevention against undesirable hot dry summer or cold winter winds [13].

5. Conclusions

Vernacular architecture was mainly developed on the principle of providing the necessary requirements through the local resources and nature’s energy. Throughout time, while architecture and urban morphology were subject to different socio-economic, cultural and political factors, different solutions have been provided, always based on the fixed environmental factor which is the climate. This study refers to the main climatic design considerations in the early stages of Nicosia’s settlement. From the analysis made above it is evident that the choice of the location of Nicosia, in the middle of Mesaoria plain, between two mountain ranges and the existence of the Pedieos river played a crucial role in the creation of the climatic conditions of the city. According to the typology study, as described, if a plot did not have any limitations, the building volumes and the courtyards were located in such a position that its longest side had the optimum orientation. In parallel, with the proper isolation the building envelope dealt successfully with matters of sun shading, cross ventilation and other bioclimatic principles. The practice of choosing the optimum orientation remained valid for as long as the degree of urbanization and the availability of space did not impose any restrictions. It was not until...
the Ottoman Rule, that these factors became apparent and the direct contact and access to the street became the prime criterion for orienting the building. Nevertheless, the strategies applied in the building form and its immediate built environment, show high adaptability to the climatic conditions. The prevalence of the central yard, the arrangement of close and semi-open spaces around the yard, the use of materials with high thermal inertia showed the environmental consideration during the erection of traditional dwellings.

Further investigation is being conducted and selected buildings are being monitored in order to proceed with the goals of the overall research programme and introduce a quantitative documented bioclimatically based approach in the rehabilitation of the built heritage.

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