Evaluation of Sustainable Design Elements in the Historic Centre of Nicosia, Cyprus

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ABSTRACT: A research project has recently been funded concerning the implementation of sustainable design elements of vernacular architecture. The research focuses on the identification and preservation of the factors and elements that contribute to the improvement of thermal comfort within traditional buildings. Following an overall architectural investigation of the areas under study, a representative number of dwellings were selected for monitoring, on the basis of their typology, bioclimatic elements and construction materials. The main objective of this paper is to demonstrate the preliminary results of the research, mainly through the evaluation of the data registered during the tabulation of about 50 vernacular dwellings in the walled city of Nicosia. This paper focuses on the identification and listing of the bioclimatic parmeters influencing the thermal performance of vernacular buildings. The results are anticipated to highlight the significance of conserving the environmental elements of vernacular architecture and enrich the rehabilitation methodology approach.

1 INTRODUCTION

The existing building environment within the urban settlements in Cyprus embraces a rich traditional architectural heritage. The preservation and rehabilitation of this heritage is of great importance with regard to the regeneration of the urban historic centres of the island. The need for scientific investigation and research on the sustainability of vernacular architecture, as one of its main characteristics, is imperative, especially in a society that gradually encourages the sustainable use of resources and the strengthening of synergies between environmental protection and development.

The research project "BIOVERNACULAR" began in July 2012 and is funded by the Republic of Cyprus and the European Regional Development Fund. The study area is the historic centre of Nicosia in Cyprus; research focuses on two neighborhoods which have preserved their original character without significant alterations.

The project aims at maintaining the bioclimatic characteristics of the vernacular dwellings and enhancing the environmentally-friendly approach in the rehabilitation techniques, through "smart" and innovative solutions. In addition to the above, another aim of the project is the establishment of a scientific methodology for assessing environmentally architectural and construction elements of traditional buildings, through systematic research and on site recording of data and the use of simulation, in order to contribute to the promotion of innovative technical solutions in the building industry. Furthermore, the collaboration of the occupants with researchers from various disciplines (architects, conservators, material engineers, mechanical engineers etc.) fosters an intergraded approach and methodology based on the exchange of experiences.

2 VERNACULAR ARCHITECTURE IN NICOSIA

It is widely accepted that vernacular architecture corresponds to the local climatic conditions. Following a review of the historic and socio-economic evolution of the city of Nicosia, the necessary documentation for the identification of those environmental design elements is acquired.

Nicosia's original building types (Figure 1) were similar to the typical rural houses of the settlements in the plains (Papadouris, 1994). The houses occupied a large area, and they were adapted to the landscape and positioned in such a way that the longest façade or main part of the courtyard would have the optimum orientation. The arrangement of individual rooms (closed and semi-open spaces) around a large irregular yard prevailed. As long as the degree of ur-

banization and the availability of the space did not impose any restrictions, the criterion of orientating the buildings was primarily climatic; hence factors such as sun shading and cross ventilation also played an important role (Danilo, 1997).

It was not until the fortification of the city (Lusignan and Venetian Times) that the available space became limited and a process of land fragmentation was initiated; in the 1920s and 1930s the new development of the urban tissue promoted the necessity of building in direct contact with the street and gradually undermined the importance of the environmental criteria (Philokyprou et al. in press). Besides the location of the building in the plot, some typological alterations had also taken place. Serial allotments along main streets enhanced the evolution of the traditional courtyard house into a "serial type house", which was much smaller in size and had an equally small yard, (Danilo, 1997). Nevertheless, the semi-open covered spaces normally located along the south side of the building, locally referred to as "iliakos", continued to be present as part of a cultural expression of the Mediterranean way of living (Philokyprou et al. in press).

Figure 1: Representative building types in Nicosia showing distinctive environmental features. Source: Authors' personal archive

The expansion of the city on the outskirts of the historic core defined by the Venetian walls that took place during the British occupation (late 19th century), along with the establishment of the "Green Line" in 1963 and the "Buffer Zone" in 1974, led to the division of the city (Papadakis, 2006) and to the neglect and partial abandonment of the historic centre. Consequently, some areas have preserved their original character without major alterations concerning the architectural elements, scale of buildings and the urban tissue, thus providing a rich built heritage available for study and research.

3 RESEARCH METHODOLOGY

The methodology presented in this paper covers all work packages of the research project "BIOVERNACULAR". Focus is on the detailed presentation of the findings of the first stage of the research concerning the evaluation of the sustainable design elements in the urban and architectural scale, through the evaluation of the data gathered during the tabulation of traditional dwellings.

First and foremost two characteristic areas which have preserved their original architectural and urban character were selected for detailed investigation. In the first work package, different typological arrangements of spaces in buildings were examined through topographic and architectural plans and on-site investigation. A scientific study on the fundamental parameters that affect the bioclimatic performance of the traditional buildings determined the selection of the most characteristic samples for further investigation.

These parameters are:

- Relationship of buildings to their immediate environment (location in the urban core, proximity to other buildings)
- Arrangement and combination of covered and semi-open spaces around the central yard
- The effect of the existence of water elements
- Orientation of the building envelope and especially the arrangement of the openings towards the south
- Sun shading projections (balconies, adjustable elements, planting deciduous trees, fitting blinds, pergolas, etc.)
- Cross ventilation and stack effect (number, size and location of openings)
- Type, material and quality of the shell (walls and roof construction, thermal insulation, building mass, colour)

The data collected were tabulated and encoded for comparative investigation and analysis. These recordings defined the basis for the selection of a number of characteristic buildings for further detailed examination and research. Data of the climatic condition in the area are currently being recorded on a daily and seasonal basis. Activities of the local occupants and human parameters (closed and open windows during the day and night, clothing, activity etc.) are also examined and assessed with regard to the satisfaction of biological and psychological conditions. Questionnaire-based research provides valuable information regarding the way occupants use their houses in relation to heating, cooling and lighting, in order to achieve comfortable living conditions. Information on the energy and water consumption is also collected.

The second stage of research includes the selection of a representative sample of buildings for monitoring temperature, humidity, lighting levels and ventilation aspects. Data loggers have been installed in the main rooms, the semi-open spaces, the inner courtyard, and in some cases on first floor spaces within the premises, to record temperature and relative humidity levels. Weather stations have also been installed in the selected study areas and in the centre of a traditional courtyard. Thermography of the building envelope will be used to provide insight into the heat flow and graphically presents the areas of energy losses. The data will be recorded and tabulated for quantitative and qualitative analysis. The thermal capacity and thermal conductivity of basic local materials (stone, mud brick, wood etc.) used in traditional buildings will be examined *in situ*, while comparisons with the corresponding values of contemporary materials will be made.

In the third stage and relevant work package of the project, six buildings have been selected to serve as case studies for modelling and simulation of the recorded data. The comparison between simulated and recorded data will be used for calibrating the digital models. In this way, a useful tool for further investigation will be acquired.

At the fourth and final stage of the project, simulation results will be used to identify the effect of several parameters (geometry of architectural elements, construction materials, building orientation, heating and cooling loads), on the indoor and outdoor thermal comfort. The above parameters and factors will set the basis for the drafting of guidelines and recommendations for the rational conservation and restoration of traditional buildings, aiming at the improvement of their energy requirements and the application of innovative solutions, by maintaining and enhancing their bioclimatic characteristics. These recommendations and solutions will also be applicable to contemporary structures.

4 DATA ENCODING AND TABULATION

Preliminary research results are presented in this paper. These mostly refer to the qualitative analysis of the typology and bioclimatic characteristics of the buildings under study. The selected study area is the neighbourhood of Chrysaliniotissa (Figure 2), located on the west of the walled city. This area is considered among the oldest and best preserved traditional parts of the core of the city.

A sample of 52 buildings, in their majority residential ones, were studied; more specifically, 45 traditional dwellings dating from the late 19th century or early 20th century and seven buildings constructed between 1995-2005. Those few new houses are replicas of the traditional buildings in terms of form, character and typology; they were constructed as part of the project “Revitalisation of Chrysaliniotissa” within the framework of the “Nicosia Master Plan”, a bi-communal development plan promoted and sponsored by the United Nations Development Programme since 1997.

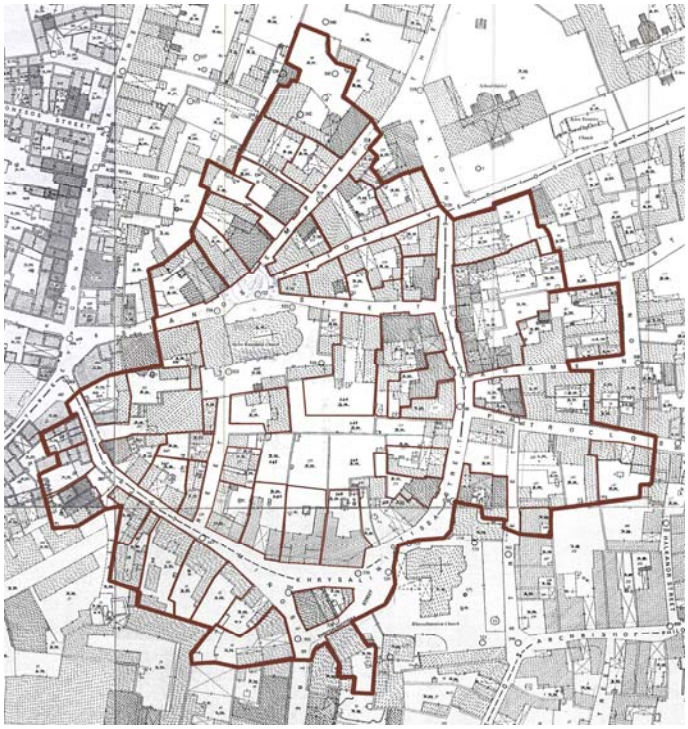

Figure 2: Study Area: Chrysaliniotissa neighbourhood
Source: Department of Lands & Surveys, Cyprus.

In the process of identifying and evaluating the environmental aspect of vernacular architecture, the following tools were used: a topographic map provided by the Department of Lands and Surveys, on site visits to the accessible buildings of the area and questionnaires concerning the way the buildings function and performing. The data were encoded and tabulated on a data sheet (A4 size) for each building, which contains all the essential information (Figure 3). The aforementioned data sheet is divided into three sections: the right column contains some identity information for the house and its location, as well as the relevant typology of the building, type of occupancy, and construction condition. The main part on the left includes all the environmental strategies and the lower left part the topographical material and photos of the building. Whenever deemed necessary, additional plans and photos are presented on separate sheets. At the bottom of the left part a brief description of the interventions that took place during the rehabilitation process is included. Emphasis is placed on those interventions that are related to the bioclimatic performance of the dwellings.

4.1 *Typological characteristics*

With regard to the “Typology”, the research revealed the three main categories of building plans:

the “I” shape, as a more compact and simple form of linear placement of the individual spaces, and the prime evolutions of this type, which are the “U” and “L” shape typologies (Danilo, 1997). The latter is in fact the most common arrangement recorded as almost half of the dwellings studied are of an “L” shape).

The central part of the building volume with regard to its interior arrangement can be further differentiated into single bay (*monochoro*), double bay (*dimeres*) or triple bay (*trimeres*) types. The triple bay prevails in the sample studied and represents about 75% of the dwellings. This arrangement offers a very convenient solution to the entrance of the house through the central bay, which functions as an intermediate semi-open space that crosses the dwelling. Through this space, called “portico”, access from the street towards the courtyard is achieved. Additionally, this space gives access to the rest of the rooms arranged on its two sides (Philokyprou et al. in press).

The “Type of Residence” varies from “occupied” to “unoccupied” and “partially occupied” depending on the duration of occupancy. The sample selected is mainly occupied all year round (39 out of 52 dwellings). The category “Construction Condition” gives information about the type of construction i.e. whether it is an original traditional building or a replica (similar to the traditional ones but constructed with conventional contemporary building materials).

The condition of the building is also stated, specifying whether it is “conserved”, “not conserved” or “in a ruin condition”. As mentioned before, there has been a rehabilitation project in the area of Chrysaliniotissa, therefore, the greater part of the buildings under study are conserved (40 out of 52); seven buildings have been recently built.

4.2 *Sustainable design elements, strategies and interventions*

The bioclimatic principles and other architectural parameters that contribute to the improvement of internal comfort are examined with regard to the following factors: heating, cooling, microclimatic environment, materials and construction (Figure 4).

As far as the “Heating” strategies are concerned, direct solar gains (H1) constitute the main principle of bioclimatic design during the winter period. Such gains are derived from the south orientation of the building and its openings.

In cases where the south orientation is not an available option, due to the location of the dwelling in the urban tissue, indirect solar gains (H2) are derived from the building envelope, as solar radiation is captured by the walls and the roof. Protection from the strong cold winds also contributes to the reduction of heat losses (H3).

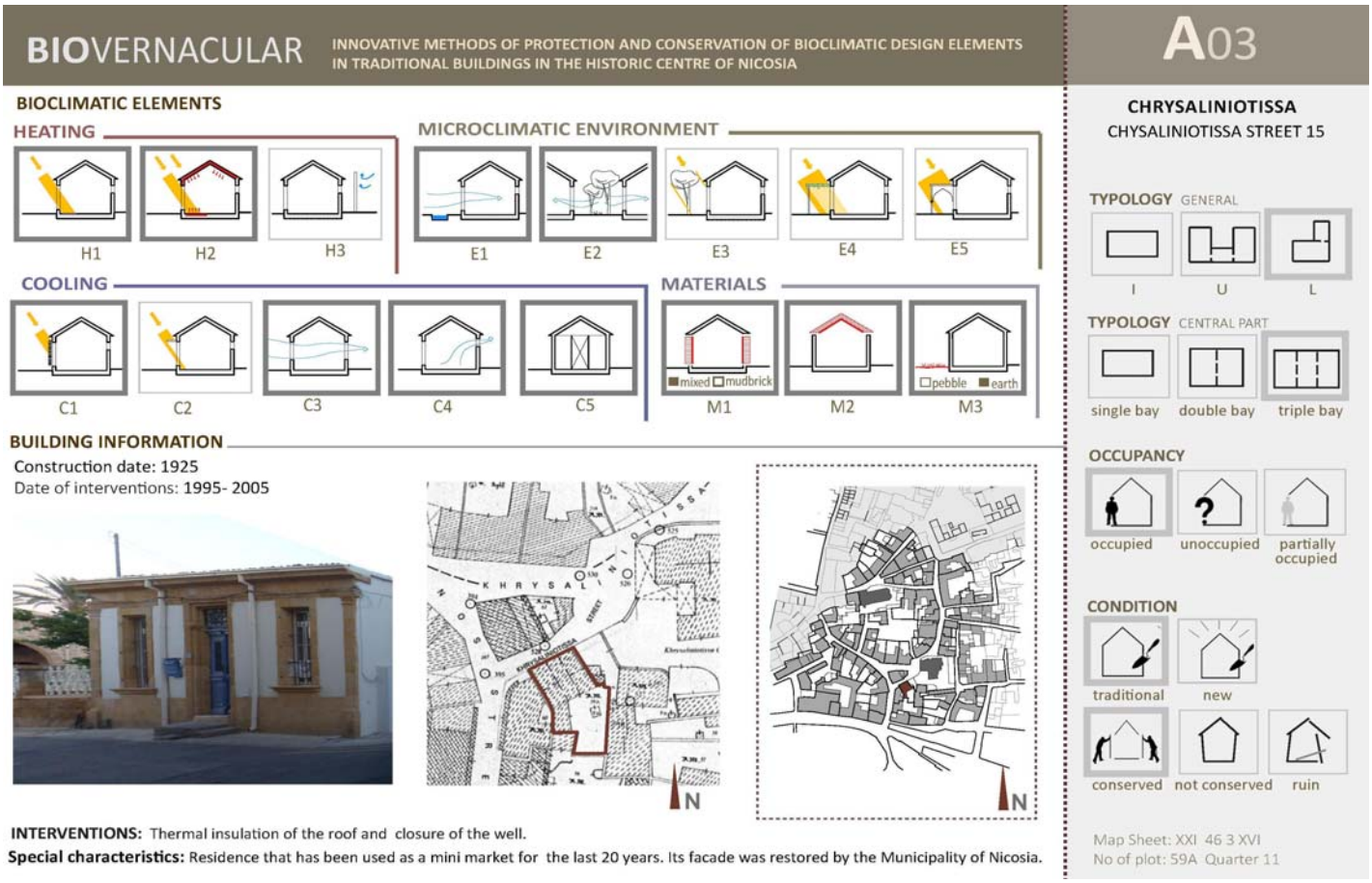

Figure 3: Representative data sheet of selected study building. Source: Research Programme Biovernacular.

As far as the “Cooling” strategies are concerned, shading and ventilation are the main cooling techniques recorded in the area under study. It is worth mentioning that the entire study sample has external shutters -solid plank or adjustable louvers- (C1), while in 96% of the sample, cross ventilation is ensured through openings (C3). The sun shading is realized by light pergolas with plants in front of the south side of the buildings (E3, E4), roof overhangs and balconies (C2).

Regarding ventilation, the movement of air through the building envelope depends greatly on the size, the shape and the position of the openings (Goulding et al.1992). The small size openings, located at a considerable height, mainly on the façade on the streets (called “arseres”), contribute to the forced ventilation and the extraction of hot air from the building envelope (stack effect) during the summer period, due to the difference in temperature and density of the air (C3, C4) (Goulding et al.1992). The semi-open spaces (“iliakos” or “portico”) also enhance the air flow, especially due to the cross arrangement of the “portico” (C5).

With regard to the strategies on the “Microclimatic Environment”, the existence of water elements (wells and shallow pools) in courtyards and in the areas surrounding the buildings, as well as the watering of the plants, provide evaporative cooling during the summer (E1). 88% of the study sample has small-scale central courtyards (E2), revealing the importance of this element in local urban vernacular architecture.

During the winter, as the surface materials (stones and/or earth) and the surrounding walls of the courtyard increase the urban heat effect, the interior temperature is higher in relation to the external environment.

During the summer months, it is noticed that in several cases (38%) the yard is being shaded by plants and vegetation (E3) or by the surrounding building volumes, and thus the interior temperature is kept at a lower level, compared to the external environment. The vegetation forms a natural protected environment, which reduces the high temperatures during the summer period, shading the building envelope and reducing the sudden changes in humidity.

Moreover, vegetation can also prevent, filter or divert the air flow, thus affecting the internal ventilation of the buildings (E2). Additionally evaporative cooling is enhanced through plant transpiration. Consequently, surrounding cool air concentrates at the lower levels, while at the same time hot uprising air drives itself outside the house through the archways. Cross openings of rooms ensure airflow in the house’s interior, causing cool breezes. During the warm summer nights, natural ventilation purges excess heat and cools the building fabric. Because of their sufficient thermal masses, vernacular building envelopes exposed to nighttime ventilation can drastically reduce peak daytime temperatures.

External shading is also provided by the use of pergolas (E4). It is worth mentioning that pergolas are commonly witnessed in rural settlements (Sinos 1976).

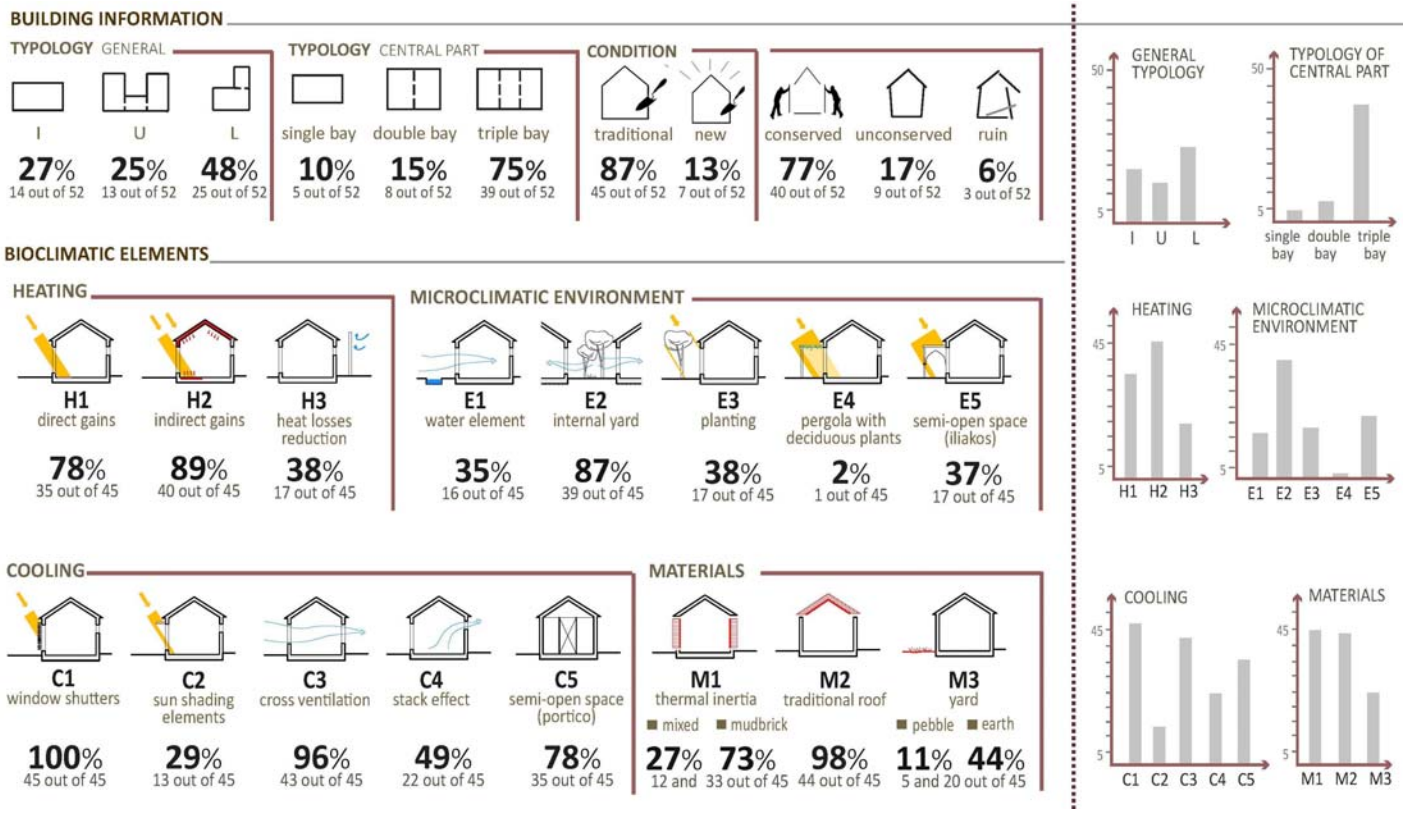

Figure 4: Summary of research results. The building information is expressed as a percentage of the whole sample (52) and the bioclimatic elements are expressed as a percentage of traditional dwellings (45). Source: Research Programme Biovernacular.

Nevertheless, in the selected sample of study buildings only one such case was recorded. This is likely attributed to the urban character of the Chrysaliniotissa study area. A more usual urban practice for shading and creating external sheltered areas is the use of 'iliakos" or other semi open spaces located in the south or south east direction; this was recorded in 14 out of 45 buildings.

Regarding "Materials", thermal inertia (M1) is secured by the thick external mud brick wall resting on a stone foundation and the roof materials. The roof construction is composed of different layers (beams/rafters, reeds/mats/timber planks, layers of mud, ceramic tiles), (Ionas 1988), offering extra insulation to the dwelling.

As far as "Interventions" are concerned, the most commonly noticed alterations are the closing of the semi-open space of "iliakos" recorded in 23 out of 45 traditional building and the replacement of the traditional inclined roof by a similar one with ceramic tiles and wooden substrate. This intervention, which is recorded in 28 out of 45 study buildings, most probably included the addition of some kind of insulation. Other interventions refer to the introduction of impermeable flooring (e.g. concrete floor) in the yard and the filling up of the well.

5 CONCLUSIONS

The analysis of the data gathered showed that special emphasis in Cypriot urban vernacular architecture was given to the cooling rather than the heating strategies. The hot climate of the area probably led to the enhancement of the cooling strategies through cross ventilation and stack effect (openings) as well as shading (pergolas, shutters, iliakoi etc.). As a result, traditional houses in Nicosia demonstrate a good thermal behavior during summer, very close to thermal comfort, without the need for any external cooling support. About half of the dwellings under study incorporate most of the identified cooling strategies. The combination of shading and night cooling reduces the interior temperature, keeping it at close levels to thermal comfort. On the other hand, the rather limited heating strategies incorporated, i.e. minimum exposure of surfaces to the south and small size and number of openings in the south facades, did not allow the house to take full advantage of the sun during the winter.

The great importance of the courtyards is also underlined through this investigation as they offer a series of environmental improvements with favourable results during all periods of the year (direct solar gains in areas around them, cross ventilation, vegetation, water elements). The arrangement of rooms around the yard in the form of an "L" shape (which constitutes the favourable arrangement in the buildings under study) leads to the exposure of more facades towards the yard, and to the creation of more suitable openings.

The above analysis highlighted the most common bioclimatic strategies incorporated in the vernacular dwellings of the walled city of Nicosia in order to provide a comfortable interior environment. The special care given to the courtyards, the semi-open spaces and generally to the cooling strategies is related to the hot climate of the country and the need to reduce the unfavourable high temperatures of the summer period within these traditional dwellings.

Future research will focus on the monitoring of temperature and humidity levels in selected buildings. The thermo-physical qualities of the local materials (i.e. stone, mud brick, wood etc.) used in the construction of traditional buildings will also be examined, in order to quantify the contribution of bioclimatic design elements to the interior thermal comfort of buildings.

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