

Evaluating sustainability and energy efficiency of a traditional housing: The case of the Samanbahçe Settlement in Cyprus

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Abstract

Built in 1896 with traditional materials and construction methods and representing one of today's rare examples of its kind, the Samanbahçe Housing in the walled city of Nicosia, Cyprus has through the years undergone modifications that have changed the housing's former sustainability characteristics. The three-pronged aim of this study includes an analysis of the original state of the site's sustainability and energy efficiency, a determination of the effects of modifications on the sustainability, and a means to suggest ways to restore the original positive features, while still meeting the contemporary needs of 21st century dwellers. Using on-site analyses, Design Builder analysis software, and interviews with residents, the authors compared and contrasted the thermal properties and total energy consumption of the various modifications to the original design. Analyses of the case study results reveal that most of these houses were modified in several different ways, with the most important modification being the either partial or total elimination of the courtyard. According to the findings, changes made in courtyard size did not result in increased cooling needs due to the constant transparency ratio, the high thermal mass of the building envelope, and the narrow streets and enclosed courtyards walls that serve to shade the buildings. By changing the A/V ratios it has been determined, however, that there was an increase in heating and lighting loads. According to the survey results, the totally enclosed courtyards in all cases have caused barriers to cross ventilation, increased humidity levels, and limited the inflow of natural light into the buildings. Thus the modifications made by residents had a negative effect on the climate responsive qualities of the houses. Based on the findings of these analyses, the authors have suggested the possible solutions for restoring and maintaining the sustainability of the housing.

Keywords

Sustainability, Climate responsive housing, Energy efficiency, Residents' modifications, Cyprus.

1. Introduction

Despite the fact that the island of Cyprus has a long summer season and a year-long wealth of sunny days (leading it to be known as “sun island”) (Florides, et al., 2001), almost none of the construction methods used today avail themselves of passive methods of building climatizing. For the past several decades, most island builders have chosen to use active systems and have ignored or overlooked the traditional passive strategies and the climate responsive features inherent in traditional methods. This insistence on active methods is threatening the advancement of sustainable construction and has led to a continuing increase in energy consumption, despite the fact that the island has to rely on off-island resources for all of its energy needs. The situation is making it imperative that the island’s construction sector adapts an architectural approach that will decrease this ever-increasing energy dependency.

An examination of the traditional architecture in the island, clearly demonstrates that passive construction strategies were successfully reflected in the building form (Dinçyürek, et al., 2003; Florides, et al., 2001; Oktay, 2002; Ozay, 2005; Oktay & Pontikis, 2008). However, very few examples of such traditional architecture have survived and among those few that have survived, many have been modified through the years in ways that have destroyed the climate responsive properties of such buildings. The combination of inappropriate architectural practices and the use of active systems in the provision of climatic comfort conditions now constitute a very real threat to the sustainable development of the entire island. It is therefore imperative that builders reestablish the use of climate responsive systems on the island. Then first step in such an achievement lies in examining the methods used in the extant examples of traditional architecture and then integrating these methods into contemporary building practices. To this end, this work focuses on one of the few remaining examples of such traditional architecture that accommodates – or used to accommodate – with the unique climat-

ic features of the island. By examining the climate responsive qualities of the Samanbahçe Housing Settlement, we aim to focus on the sustainable architectural features and examine the ways this complex can serve as an example for new construction strategies.

Through the years, many of the individual units of the Samanbahçe Housing Settlement have been modified to lesser or greater degrees by their residents so as to meet their perceived needs. In addition to the changes made by the residents themselves, in 2004 the outer shell of the houses was subjected to an updating process by the United Nations Development Programme (UNDP). Residents reported that the combination of all of these changes to the building form also changed the climate comfort features of the interiors of the units. The aims of this current work have thus been directed at determining of the effects of the changes (caused by the entire, three-quarters and half enclosing of the courtyards of the units by their residents and by the changes made to the building’s envelope by the restoration efforts of the UNDP) in heating, cooling, and lighting loads via modeling and simulating; and conducting a survey of residents to determine their perceived satisfaction of climatic and visual comfort features, relative to the modifications of their houses.

A third focus of this work has been to provide suggestions as to how the current conditions of the housing complex can be evaluated and modified in such a way that the complex as a whole will become more energy efficient and sustainable while meeting the contemporary needs of its residents. As a primary step, we examined the history of the traditional settlement so as to determine its original design and function. We next engaged in a modeling and simulation process to evaluate the building in terms of both its current thermal and visual performance factors. A survey carried out with current residents sheds light on the ways the residents use the dwellings today and how satisfied they are, or are not, with the performance of their dwelling.

2. Background research focusing on climate responsive strategies

Many researchers have investigated cases in different locations of Cyprus, either emphasizing the importance of the courtyard, which is a very prevalent feature in traditional houses of the island, or comparing and contrasting traditional and contemporary buildings as a means to obtain data that demonstrates the climate responsive qualities of the traditional houses. In her evaluation of the vernacular urban and architectural patterns at the Northern Cyprus, Oktay (2002) discusses the courtyard, which she defines as a space that guarantees the climatic comfort in a hot and dry climatic zone and says that the courtyard represents a design tool in the design of more sustainable new developments. Similarly the investigation carried out by Philokyprou & Michael (2012) emphasizes the significance of the inner courtyard as a microclimate regulator. Their investigation evaluates the environmental behavior of traditional architecture and reveals the climatic design elements of Cyprus' traditional architecture, namely the passive strategies utilized for heating and cooling.

In their studies of traditional and modern houses in Cyprus, Florides et al. (2001) simulated the energy flows of both traditional and modern houses by means of a computer program. The results indicate that such design features and applications as high ceilings and doors and positioning openings towards the prevailing night winds resulted in a low cost house offering the same temperature conditions as a highly insulated and expensive modern house. Similarly, Dinçyürek & Türker (2007) underlined their beliefs that the inherent in the island's traditional houses are a number of principles that can be learned and applied to today's architecture. Setting off from this perspective, they defined those design principles suitable for contemporary housing that both reflect the existing unique patterns in traditional housing of Cyprus and that will ensure sustainability. Another study carried out by Dinçyürek et al. (2003) constitutes an analysis of the traditional Mesaorian houses that focuses on that site's

climatic design parameters, including function, building form orientation, layout and material. They investigated climatic performance through measurements of the arcade and an interior room. Their results show that Mesaorian houses respond to the environment in a manner appropriate to their functions and meet the perceived comfort needs of their occupants. The authors suggested that today's designers adapt some of the features of these houses into their contemporary design principles. Kalogirou et al. (2002) presented the heating and cooling energy consumption results in terms of the thermal mass of the buildings. The results of the simulation support the understanding that heating energy consumption decreases whereas cooling energy consumption slightly increases. These authors also evaluated such different design parameters as optimum overhang size, air gap size and wall thickness have also been carried out. They found that southern exposure thermal walls are always advantageous in terms of energy loads.

The problems faced in Cyprus are not unique to that particular island and many other researchers working in other places in the world are also focusing their attention on issues of sustainable, energy efficient and climate responsive traditional houses of different scales. One example from Malaysia which is a comparison between traditional Malay House and new forms of construction shows the climatic responsive qualities of the traditional houses with respect to environmental comfort (Hanafi, 1994). Likewise, Ealiwa et al. (2001) have reviewed the results of thermal comfort survey which were carried out in traditional and contemporary building types in Libya. They used full-scale measurements and a questionnaire based on environmental parameters and human thermal comfort responses from 51 buildings. According to their results, occupants are more satisfied and thermally neutral in older type, naturally ventilated buildings than they are in new air-conditioned buildings. Another comparison, this time between traditional and contemporary house in Thailand, was carried out by Antarikananda et al. (2006) in order to

investigate whether traditional houses demonstrate better thermal comfort conditions than do contemporary structures. Using a simulation model, they concluded that the traditional housing of Thailand provide useful architectural design responses to climate. Singh et al. (2009) conducted an extensive study on thermal performance of northeastern Indian vernacular architecture. Their field study includes the survey of traditional houses, field tests and occupants' selection of thermal sensation on the American Society of Heating and Air-Conditioning Engineers (ASHRAE) thermal sensation scale. They included measurement of temperature, humidity and illumination level in their field survey. Their work revealed that traditional houses work much more efficiently in all seasons other than winter.

This review of research studies demonstrates that there is a direct co-relationship between the climatic comfort of a building and the quality of its passive systems. Reducing energy consumption, using natural resources and providing comfortable, healthier and sustainable living spaces are the aims of climatically responsive building design (Hui, 2010). There are, however, many times when in a specific period of the seasons, supplementary active heating and cooling systems will be necessary in order to provide thermal comfort conditions. In such cases, the thermal performance of the building's passive energy systems is the determining factor in the amount of energy required. Since the building form is one of the most important components with respect to total heat loss and gain of the whole building, it becomes the main determinant of the amount of energy consumption caused by the active systems. As the building form changes, the facade area surrounding the building, consequently the volume of the building and the heat flow amount through itself will change respectively. Moreover the thermophysical properties of the building envelope are the indicator of the amount of heat gain or loss through the building envelope. Therefore, since the building envelope and form are the primary determinants of both the indoor climatic conditions

and the amount for active energy consumption, they will be analyzed for the case of the Samanbahçe Housing in the following sections.

3. Identifying and analyzing the climate responsive Samanbahçe Houses

The traditional Samanbahçe Houses reflect the major characteristics of climate responsive house design. In this work, these houses will first be described with their general characteristics and then will be analyzed in terms of climate responsive design parameters.

3.1. Historical background

The Samanbahçe Housing ranks as the first public social housing project in the Walled City of Nicosia. Although the exact date is not known, documents tell us that the complex was first partially built in 1894, a period that coincides with the British colonization of the island. The increase in population at that time had given rise to an increased need for housing, so permission was granted to the Evkaf Charitable Foundation (ECF) to build on this parcel of farm land within the city walls (ECF Document, 2004).

The housing was originally built as welfare housing for low-income families and has, since then, been occupied by low and middle income families for more than a hundred years. The complex still continues to be operated and run by the same foundation. Today registered as third class historic buildings, the housing attracts the visit of experts and tourists alike (Figure 1). The complex, which was built in stages over time, currently comprises 72 housing units. Most of the units were completed during the first stage in 1900, while new houses were added in 1949 and some later houses subsequently added.

Today the Samanbahçe Complex faces problems brought on by socio-economic decline. Beginning in the early mid-1980's, the local residents began to abandon the walled city and these earlier residents were soon replaced by immigrant worker families. Crime rates began to rise with the influx of this new low-income population and this also ushered in a process of decay in the walled city. Because this



Figure 1. Roof silhouettes of the Samanbahçe Housing.

ongoing physical deterioration poses a threat to the local/traditional characteristic of the district, a comprehensive master plan was implemented. Within the context of this plan, a revitalization project financially supported by the UNDP was implemented by United Nations Office for Project Services (UNOPS). Restoration work started in 2003 and was completed in 2004. This work focused on three major concerns:

- Upgrading the existing infrastructure, including upgrades to the power supply, telephone lines, sewerage system and water supply.
- Landscaping of the whole area: Pedestrianization of streets, restrictions placed on vehicular traffic, clear separation with pedestrian routes, introduction of appropriate street furniture and lighting and improvement of parking areas.
- Rehabilitating traditional buildings: Restoring the facades and roofs of the houses and the historic fountain (ECF Document, 2004).

Despite these efforts, the revitalization project failed to stem the process of physical and social decay. Many of the residents of Samanbahçe voiced dissatisfaction with the renewal efforts, saying that the changes made were only cosmetic. Moreover, such present factors as the changes in the life-style of inhabitants, the inadequacy of modern sanitary conditions that can meet contemporary needs, the small sizes of the dwellings, the lack of regular maintenance, lack of awareness and low educational levels of current residents have all caused this process of physical and social decay to continue today (Doratlı, et al, 2001), (Vehbi & Hoşkara, 2011), (Yıldız, et al., 2009). It has become evident that the changes made to the complex, as a whole and in part, through the years have also impacted upon and significantly changed the original climate responsive features of

the housing.

3.2. Climate responsive Samanbahçe Houses

The study includes an examination of the climate responsive design strategies employed in hot and dry climates that focus on the unique climatic conditions of the region. Following this determination, the traditional Samanbahçe Housing Site was evaluated in terms of climatic conditions and design criteria such as site and orientation, building form and building envelope.

3.2.1. Climatic condition in Nicosia

Nicosia has a composite climate with hot and dry summers and rainy winter seasons. Located in central Cyprus, Nicosia is situated between longitudes 33°24'E and latitudes 35°09'N. The city is hot and dry during its long summer season that extends from April to October. Throughout the year, July is usually the warmest month, while the coldest month is usually January. Temperatures vary between 9°C–12°C during the winter, and often exceed 42°C in summer. Highest rainfalls occur between December and March. The prevailing wind comes from a westerly direction with an average wind velocity 3.7 m/s (Department of Meteorology, 2012).

3.2.2. Site and orientation

The Samanbahçe Settlement displays a rigid grid street system with straight north-south and east-west orientations (Figure 2). The building units in the existing settlement are aligned along a north-south axis and oriented towards the east and west, thus ensuring that they all share equal amounts of solar radiation. However, the west-facing windows are particularly problematic in summer because the heat gain is maximized during the later afternoon, typically the hottest part of the day.



Figure 2. Site plan of the Samanbahçe Housing (ECF Document, 2004).

Nicosia has both intense solar radiation and high air temperatures in summer, both of which are the major sources of climate discomfort for the city. Shade from this solar radiation is an important requirement for cooling energy consumption, both for outdoor and indoor areas. During the summer season, the Samanbahçe Houses are shaded by the walls lining the narrow streets (Figure 3), which are the main determinants of shaded or irradiated external wall area and consequently the annual amounts of heating and cooling energy consumption.

3.2.3. Building form

The building form is one of the most effective design parameters for providing indoor climatic comfort conditions. The thermal performance of a building envelope is also influenced by the building form. Therefore, the building form is one of the reasons of the amount of heat transfer through the building envelope. As is known, the facade area of the building and consequently the total heat loss or gain may change due to the change in the building form. It is possible to determine a lot of building forms that yield same volume, but different facade area (Yılmaz, Koçlar Oral et al., 2000). Therefore, the ratio of total facade area to building volume (A/V) is an indicator describing the building form.

The Samanbahçe Housing Units were constructed around a courtyard and aligned inward. Courtyard houses are generally the most preferred building form type in those climates as they minimize the heat conducted from

outdoors and provide shade for the dwellings in the summer. On the other hand, in hot dry climatic regions the geometry of the courtyard considerably affects the facade area and the volume of the building, and consequently the A/V ratio which directly affects the generated heat gain and hence, the required cooling and heating loads. Thus, the courtyard directly affects the amount of energy loads required.

Similarly, daylight represents another of the most important parameters that are modified by the effect of courtyard dimension. When considering daylight performance in a courtyard house, window size and the courtyard wall area and color, which affect the illumination level, are usually the first key factors to be considered. Therefore, the dimensions of the courtyard walls and their reflectance features can affect the distribution of daylight in a house and thus can increase or decrease the total amount of daylight received. This, in turn affects the amount of lighting energy consumption (ESRU, 2012).

In the Samanbahçe Houses, the openings that face the courtyard pro-



Figure 3. Axial street view of the Samanbahçe Housing.

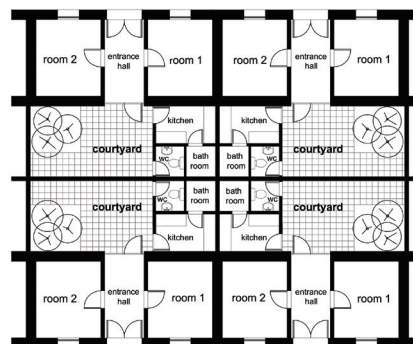


Figure 4. Typical ground floor plan of the Samanbahçe Houses (ECF Document, 2004).

vide natural ventilation as well as natural illumination. The courtyard acts as a ventilation shaft bringing in cooler air. The prevailing western wind is one of the main determinants of natural ventilation in the buildings. Each house has a courtyard and main entrance openings oriented towards the west or east; thus the central space/the sofa receives cross-ventilation through the openings to the street and courtyard. As originally built, the well-defined, open-to-sky courtyards of the Samanbahçe Houses, thus constituted climatically comfortable spaces for the dwellers (Figure 4).

3.2.4. Building envelope

The traditional Samanbahçe Houses were developed through localized experience to meet the everyday needs of the occupants and to provide comfort. Local availability and the thermal effects of the materials according to climate were the major factors that were considered in the construction of the building envelope (Florides, et al., 2001). These weather conditions provided the right conditions for the development of adobe architecture in the region. Sun-dried earthen bricks (adobe) are the most common walling materials. These bricks are made of earth, gravel, clay and water that are mixed and bound together with straw, grass or livestock hair, left to set as a mixture overnight, and then shaped into blocks and dried in the sun (Dinçyürek, et al., 2003). The finished 50 cm. walls also have a layer of gypsum plaster coating each side.

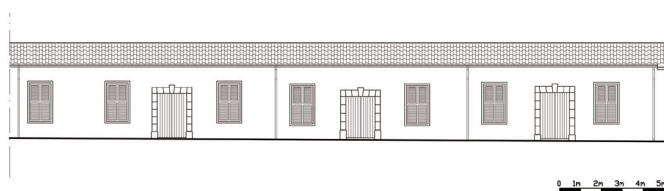


Figure 5. Partial facade drawing of the Samanbahçe Houses (ECF Document, 2004).

Table 1. Existing opaque components details (Base Case).

Opaque components	Material	λ value W/(mK)	Thickness (m)	U Value (W/m ² K)
External walls	Gypsum plaster	0,40	0,02	U=0,78
	Adobe	0,46	0,46	
	Gypsum plaster	0,40	0,02	
	Clay Tiles	1	0,025	
Pitched Roof	Earth	1,28	0,10	U=2,93
	Wood blocks	0,14	0,03	
	Gypsum plaster	0,40	0,03	
Ground Floor	Gypsum plaster	0,40	0,03	U=3,4
	Marble	3,5	0,03	

In hot climatic zones, buildings should be designed to modulate the outdoor temperature swing. In the traditional architecture examples found in this type of climate, those materials with greater thermal mass were selected to accommodate the time lag of the building envelope. In Cyprus, which typically has large daily temperature fluctuations, adobe walls have been used to construct buildings of a high thermal capacity. This capacity both helps repel the daytime heat and maintain the night-time coolness inside the building for a longer period. The thermal capacity of the adobe wall delays the heat transfer to the interior of the building by absorbing excessive heat for several hours. On the other hand, this thermal mass, which has higher surface temperatures on the outer side, will rapidly lose heating energy to the atmosphere via radiation at night, thus starting the next day at a cooler level (Manioğlu & Yılmaz, 2008), (Yılmaz, 2004). Consequently, the thermal mass of the building envelope is one of the main reducers of annual cooling energy loads.

Figure 5 depicts the facades of the houses including the main entrance doors, which have frames made of limestone, windows with wooden shutters, and the red tiled roofs. A detailed description of the traditional Samanbahçe house's wall, floor and roof thermophysical properties -such as thermal conductivities (λ) and overall heat transfer coefficient (U value)- is given in Table 1. Windows are single glazed with wooden sashes. The overall heat transfer coefficient of the transparent component (U_w) is 3.63 W/m²K. The transparency ratio of the main facades is 16%, while this ratio is 0% on courtyard facing facades. In this climate, shutters, which served as the original part of the housing scheme, have traditionally been kept closed throughout the day in order to provide privacy and to balance the sunlight seeping into the interior spaces.

4. Case study: Analysis of the Samanbahçe Houses in terms of sustainability and energy efficiency

A two-step method was used to carry out the field/case study directed at

meeting the stated aims of this work:

- Modeling and comparing the cases: First, the modifications made to the Samanbahçe Houses over time have been classified. In order to evaluate and compare the performance of every different case, a dynamic thermal simulation program, “Design Builder” has been used for modeling and simulating the energy flows and the annual heating, cooling and lighting loads (Design-Builder, 2012).
- Questionnaire survey: The survey was designed to determine both the user’s day and night satisfaction levels and the residents’ perception and satisfaction levels of the indoor environment.

An analysis of the Samanbahçe Houses shows that multiple changes have been made to many of their general plans and building forms. Most of the residents modified their houses so as to enlarge them and to at least partially solve the problems rising from inadequate physical and sanitary conditions in kitchens, baths, and WCs. The modifications to the houses were classified into three general categories and these are given in Table 2.

The unmodified, original situation of the Samanbahçe House has been modeled in order to establish the heating, cooling and lighting loads of the “Case 1” building. One of the most popular modifications made by residents has been the enclosure of half of the courtyard, which was done to increase interior space (Case 2). In some cases the residents obtained additional space by enclosing three-fourths of the courtyard (Case 3). In some houses the courtyard has been totally enclosed so as to enlarge the house space (Case 4). The building envelope details are given in Table 1, for Case 2, Case 3 and Case 4. For Case 5, a major change was made by the UNDP when it removed the soil and mud layer on the roof construction and replaced it with a 0.02 cm. eps insulation layer. The transparency ratio for the courtyard-oriented facades of modified form is 0 %. Case 2, Case 3 and Case 4 models are based on A1, B1 and C1 alternatives from Table 2. According to the models, the determined A/V ratio for Case 1, Case 2, Case 3,

Table 2. Floor plans modified by the residents.

FLOOR PLANS MODIFIED BY RESIDENTS			
1/2 of the courtyard enclosed (A)	3/4 of the courtyard enclosed (B)		the entire courtyard enclosed (C)
Aksu Street, No.7 (A1)	Guneysu Street, No.3 (B1)	Guneysu Street, No.8 (B2)	Chelebi Street, No.11 (C1)
Chelebi Street, No.2 (A2)	Chelebi Street, No.4 (B3)	Guneysu Street, No.7 (B4)	Ibn-i Sina Street, No.18 (C2)
	Aydin Street, No.3 (B5)		Aksu Street, No.10 (C3)

Case 4 and Case 5 are 1,3 – 1,1 – 1,12 – 0,88 and 1,3 consecutively.

4.1. Analysis of energy requirement

We used the dynamic thermal simulation program called “Design Builder” (Designbuilder 1.2 User Manual, 2006) to carry out an evaluation of the performance of the existing building annual loads. This program provided us with the annual heating, cooling, and lighting loads of the house and assisted us in modeling and simulating the annual energy flows of the traditional Samanbahçe Housing.

The comfort value of indoor temperature was assumed to be the universally accepted standards of 19°C for the heating period and 26°C for the cooling period. The indoor air temperature in all spaces of the building was assumed to be equivalent and calculations were done by considering the building as a unit with different zones. Since Nicosia’ climatic data are not available within the weather data given by Design Builder, International weather for energy calculations (IWECC) weather data for Paphos (which has the closest climatic data with Nicosia) has been taken from ASHRAE Weather Design Data and used in the simulation. All calculations assume that windows are covered by shutters. Four housing units have been taken as one building group with a central courtyard in order to show the modifications of courtyards made by residents. In addition,

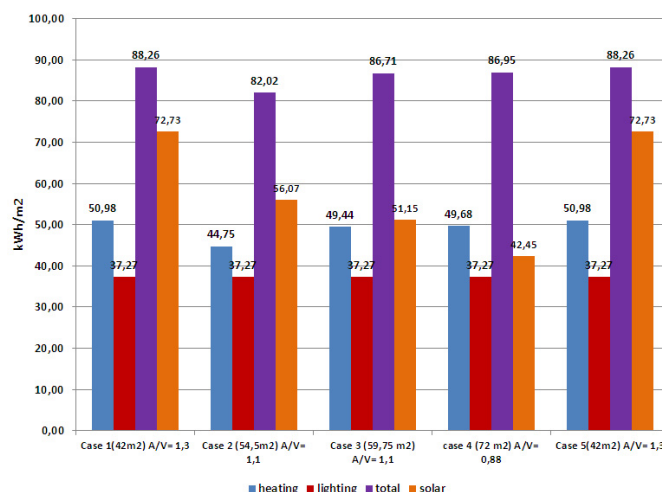


Figure 6. Heating, lighting and total loads and solar gain occurred per m².

each unit has been analyzed and modeled according to their individual and different zones and then simulated for each case. To simplify the simulation process, the effect of the shading of parallel buildings was represented by a wall. Heating, lighting loads and solar gain variations for each zone of all cases are given in Table 3. By obtaining total loads of all cases, the calculation of heating and lighting loads and solar gain per m² assist in comparing loads and gains proportionally. Heating, lighting, total loads, and solar gain occurred per m² are expressed in Figure 6. All loads are estimated on an annual basis.

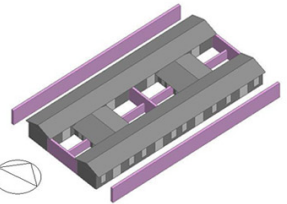
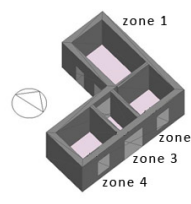
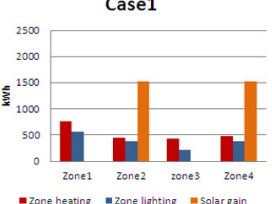
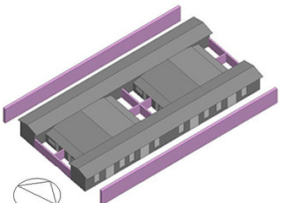
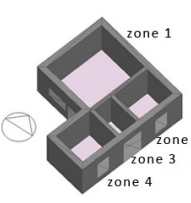
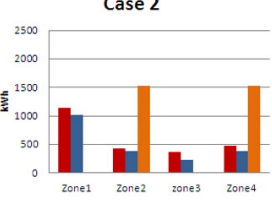
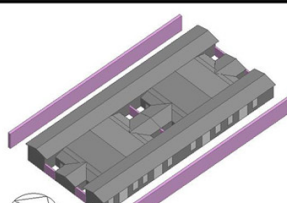
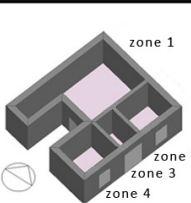
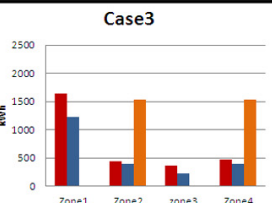
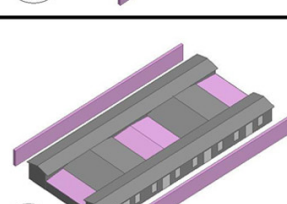
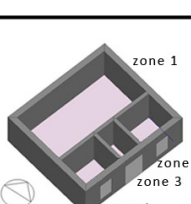
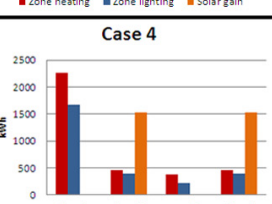
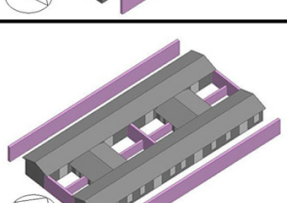
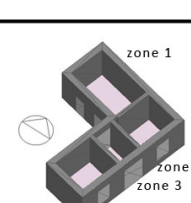
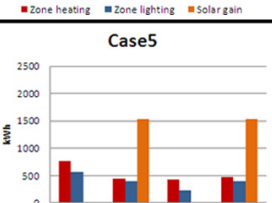
As mentioned before, the distances between buildings, the courtyard's surface and volume and the thermal mass of the building envelope have been determined as a basis for the comparison between the energy loads of the different cases investigated. The evaluation of simulation results can be summarized as follows:

- Table 3 demonstrates that both the zone heating and lighting loads, and the solar gains are the direct results of the dimensional modification and transparency ratio of the zones. Since all the courtyard dimension modifications directly affect the dimension of Zone 1, the heating and lighting loads of Zone 1 are significantly higher than the other zones.
- Solar gains only occurred in Zones 2 and 4. Since the transparency ratios of these zones are not affected by the modification of the court-

yard, the lighting loads and solar gains are equal for all cases.

- Modifications carried out to the courtyard directly affect the area of courtyard oriented facade of Zone 4. Consequently the heating loads of Zone 4 display a slight decrease in Case 2, Case 3 and Case 4.
- The heating loads variation in Zone 1 directly affect the heating loads of Zone 2 by the heat transfer occurring through the shared internal partition.
- When examining all cases in Figure 6, no cooling loads occur for Case 1, Case 2, Case 3, Case 4 and Case 5.
- Case 1 always provides the lowest heating, lighting and total loads.
- Case 4 provides the highest heating, lighting and total loads. The gain in internal space caused by modifying the courtyards of Case 2, Case 3 and Case 4 results in a significant increase in heating loads and lower heat gain obtained by solar radiation. Moreover, the increase in area and volume of the internal spaces brought by these modifications also brings about an inevitable increase of heating and lighting loads.
- When comparing Case 1 energy consumptions with other cases, it was seen that the heating loads increased by 14% in Case 2, 38% in Case 3 and 67% in Case 4.
- When analyzing lighting loads, Case 1 and Case 5 have the same rates, whereas these values increase by 30% in Case 2, 42% in Case 3, and 71% in Case 4.
- The total loads of Case 1 increase by 20% in Case 2, 39% in Case 3 and 68% in Case 4.
- The percentages of heating load in total load for the Case 1, Case 2, Case 3, Case 4 and Case 5 are 58 %, 55%, 57%, 57% and 58% respectively.
- The percentage of lighting load in total load for the Case 1, Case 2, Case 3, Case 4 and Case 5 are, 38%, 40%, 41%, 39%, 38% respectively.
- Case 1 and Case 5 provide similar loads because the original plan type has been protected in both of these cases. The modification made by UNDP has no effect on the heating loads.

Table 3. Heating, lighting loads and solar gain variations for each zone of all cases.

Building Groups		Housing Units		Heating, Lighting Loads and Solar Gain
CASE 1 CASE 2 CASE 3 CASE 4 CASE 5		A/V=1.3		Case1 
		A/V=1.1		Case 2 
		A/V=1.1		Case3 
		A/V=0.88		Case 4 
		A/V=1.3		Case5 

- When examining energy loads per m^2 in Figure 7, it can be seen that the variations of heating, lighting and total loads according to each case do not follow the same trend as those determined according to A/V ratios. It is possible to say that loads per m^2 represent only the areas variation effect, whereas A/V ratio represents the collected effects of both area and volume.
- Since the transparency ratios are equal in all cases, by changing the A/V ratio, the solar gains per m^2 reduce by 23% in Case 2, 30% in Case 3 and 42% in Case 4.

4.2. Evaluating residents' thermal satisfaction

In parallel to the measurements, questionnaire surveys were also conducted with forty-three residents in

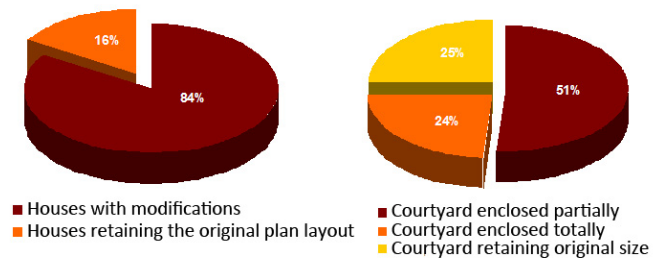


Figure 7. Evaluation of the physical conditions of the Samanbahçe Housing.

order to determine the degree of thermal satisfaction with the physical environment. Five of the houses were locked (or non-occupied), nine out of total number of residents did not want to participate, and fifteen out of the total number of residents could not be reached; thus, the evaluations were carried out with a total of forty-three questionnaires. The questions asked focused on the physical conditions of the houses, residents' annual thermal and visual perceptions, along with their demographic characteristics.

In their responses to questions regarding the physical conditions of houses, the majority of the residents (84%) stated that they had made significant interventions to their houses, including some spatial additions to the courtyard space of their houses and/or changing the spatial layout of their houses by demolishing some interior walls. Generally, due to the insufficient physical and sanitary conditions in kitchens, baths, and WCs, some residents have rearranged wet spaces and kitchens and have converted their courtyards into living and dining spaces. The rest (16%) of residents stated that they had only carried out some repair jobs, such as renewing the finish layers of walls, floors and roof. This means that their interventions were very superficial and in this way their houses generally retained the original plan with no additions. Almost half of the respondents (51%) stated that they had converted some part of the courtyard space into interior spaces, whereas 24% of the respondents stated that they converted almost the entire courtyard space into interior spaces. The rest (25%) of the respondents reported that they use the courtyard as an open

space (Figure 7).

To determine residents' annual perceptions, a resident survey aimed at evaluating their perceptions of the houses in terms of thermal and visual comfort was conducted. In the modeling and simulation process, the Samanbahçe Houses were investigated only from the perspective of annual heating, cooling and lighting energy consumption. However during the survey, in addition to heating, cooling and lighting conditions, the respondents were also asked to evaluate their living environment in terms of ventilation and humidity. Residents' annual evaluations for both heating and cooling conditions of their houses are the same; 58% of the respondents stated that they are satisfied with the heating and cooling conditions of their houses, whereas 42% of the respondents stated that they are dissatisfied with the heating and cooling conditions of their houses. The values that emerged for lighting and ventilation are the same as well. Some respondents (60%) are satisfied with the lighting and ventilation conditions of their houses, whereas the rest of them (40%) reported dissatisfaction (Figure 8).

It was found noteworthy that the residents who expressed their discomfort with humidity are also those residents who converted their courtyards partly or totally into the interior spaces. It has been determined that 100% of the residents who totally enclosed their courtyards reported a problem of humidity, whereas only 70% of residents who partially enclosed their courtyards reported such problems.

For the purpose of evaluating visual conditions of spaces, the respondents were asked whether they use artificial lighting during day time hours. A total of 39% of the residents who stated that they are generally out of their houses during daytime hours, also stated that they don't need to use artificial lighting during the day, while 35% of residents indicated that they sometimes use artificial lighting and 26% of residents, most of whom had enclosed the courtyard into interior space, indicated that they frequently use artificial lighting during day time hours. The need to keep the shutters closed is yet another

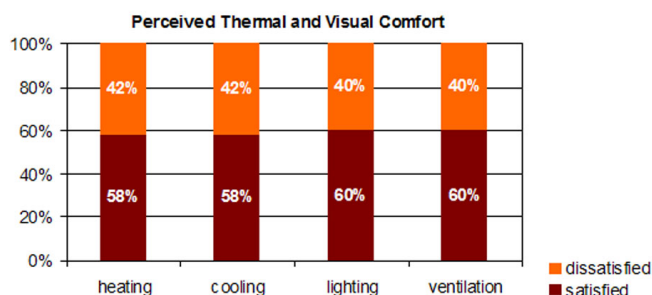


Figure 8. Residents' thermal and visual perceptions in the Samanbahçe Housing.

er reason why residents use artificial lighting. The residents use these shutters, which are original to the houses, in order to adjust the amount of sunlight entering the interior spaces (see the picture in Figure 3 and the facade drawing in Figure 5). Respondents were also asked to describe the kind of light they use in interior spaces. A total of 49% of respondents stated that they use incandescent light; 42% stated that they use fluorescent light; and 9% of the respondents stated that they use both incandescent lamp and fluorescent light.

The preferred heating systems in the Samanbahçe Houses by residents are, firstly, portable heaters such as gas or electric (45%) and, secondly, split (heating and cooling exchangers) (35%). Some residents (20%) have been using both systems complementary to each other. Residents report that they utilize heating systems six and an half hours per day during three and a half months of the year on average. Heating fuel includes fossil fuels (14%), electric (56%), and bottled gas (30%). Residents report that they pay an average of 90 Euros per month for heating. Preferred cooling systems by residents in the Samanbahçe Houses, are, in order of use, air-conditioners/ heat exchanger split conditioners (31%), fans (27%), and natural ventilation (24%). Some residents (18%) report using two or three systems complementary to each other. Cooling systems are used six hours per day during three months of the year on average. Residents pay an average of 100 Euros per month for cooling.

Despite the fact that the modeling of the Samanbahçe Houses indicated a zero cooling load, resident surveys revealed an annual cooling cost. This contradiction most likely arose from the fact that the standard limit value of cooling comfort temperature was taken as 26°C, while residents preferred to cool their houses to lower temperatures (18-20°C).

5. Conclusions

This study presents an evaluation of energy efficiency and sustainability of the Samanbahçe Houses. First, the climate responsive design characteristics

of the traditional Samanbahçe Houses have been explained and then, modifications made by residents have been classified and investigated. In summary, the results of the modeling and simulation analyzes, combined with the results of resident survey, demonstrate that:

- None of the building form has any cooling needs. Since the modified forms of Case 2, Case 3 and Case 4 cause an increase in area and volume of buildings while the transparency ratio did not change, this situation have resulted in a reduced amount of irradiation received in summer, resulting in no energy requirements for cooling. The traditional materials used in the building envelope may be the reason that such a result was obtained. Even though no numerical measurement data were collected, this can be explained by the significant thermal mass effect presented by 50 cm. thick adobe wall. Moreover, because of the narrow streets, the reduced amount of radiation can result in zero cooling loads. Due to the decreasing the volume of the courtyard, the courtyards walls became closer, resulting in the fact that they form an external obstruction. Thus, the combination of these modifications can be resulted in zero cooling loads.
- When determining the heating and cooling loads, one should not only consider the area of the building, but also the area of the building envelope where the heat flows occurs and the volume of the building which is surrounded by this envelope. Thus, decreasing the A/V ratio tends to decrease the annual heating, lighting and total loads per m².
- Transparency ratio and A/V ratio are the main parameters that determine the energy loads in buildings. Transparency ratio affects directly the solar gain and the consequent heating and cooling loads. Thus, the modifications made in courtyards affect the variation of energy loads by changing the A/V ratios.
- Our investigations have determined that all cases of totally enclosed courtyards obstruct cross ventilation, increase humidity levels, and

limit the inflow of natural light into the buildings. Decreasing the courtyard dimension also increases the lighting load by an average of 38–41% on total energy consumption.

After reviewing the major results of the study, it is possible to suggest some proposals including precautions, regulations and rules, which can provide guidance for the future sustainable development of the Samanbahçe Housing. While doing so, however, it is important to state that these proposals are not supported or demonstrated by numerical models. In this work, only the existing situation of the houses was modeled in order to make the evaluation possible. The proposals have been offered by keeping in mind that the strategy for sustainable housing should involve the “actors” such as producers, management and residents (Huong & Soebarto, 2011) and --more importantly – that without the cooperation of residents, that strategy would be insufficient (Crosbie & Baker, 2010).

First of all, removing the added spaces in the courtyard and using this space again as a courtyard will enable the houses to regain their climate responsive and sustainable qualities. For this purpose, the management (the Evkaf Foundation) should ban residents from making any modifications to the houses, and should limit number of individuals allowed to reside in one unit in light of the fact that the physical conditions of the houses are inadequate for larger size families and there is no possibility of extension. Moreover, the Evkaf Foundation should guide residents in gaining an awareness of the capabilities inherent in natural sources and inform them about the kinds of lower energy consuming devices and equipment they can choose for heating, cooling, lighting, water supply and fuel type. We should also acknowledge the fact that an island that has very rich solar radiation like Cyprus, should utilize solar energy as an alternative and energy-saving energy source.

As residents vacate their units, the foundation might also consider making changes to the demographic make-up of each unit. To restrict the numbers of residents living in each unit, they may try to find new types of residents,

such as young single professionals or seniors looking for independent living for one or two persons. The foundation might also considering adjoining some of the units to provide more spacious dwellings for those families who need the space.

This study and its results are specific to the individual Samanbahçe Houses conditions. More general results can be obtained by making different assumptions and additional air flow and humidity measurements. Repeating the calculations by taking into account the effects of natural ventilations may lead to the formation of and convenient architectural solutions for energy efficient design.

When evaluating traditional houses we understand that the design parameters of these houses present optimum values that ensure thermal comfort from the energy efficiency point of view. When any modifications to a traditional home are being carried out, the work undertaken has the inherent aim of optimizing the comfort conditions and energy consumptions. In other words, the remarkable role of climate responsive design parameters should be taken into consideration not only while modifying such houses but also while designing and constructing new housings. Last but not least, once again this work has demonstrated that there are many things to learn from traditional climate responsive houses.

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Geleneksel bir konut yerleşiminin sürdürülebilirlik ve enerji etkinlik açısından değerlendirilmesi: Kıbrıs Samanbahçe Yerleşimi örneği

Kıbrıs adası iklimsel nitelikleriyle güneş adası olarak adlandırılmasına rağmen, günümüzde adada inşa edilen binalarda pasif sistemlerden çok aktif sistemler kullanılmaktadır. Oysa enerji üretimi açısından dışa bağımlı olan adada enerjiyi etkin kullanabilmek için, geleneksel binalarda kullanılan pasif iklimlendirme sistemlerini ve iklimle dengeli tasarımın ilkelerini ortaya çıkararak bu ilkeleri yeni inşa edilecek binalarda kullanmak son derece önemli bir konu haline gelmiştir. Adadaki geleneksel binalar incelendiğinde hepsinin iklimle dengeli nitelikler taşıdığı, ancak pek çoğunun kullanıcı müdahaleleri sonucunda bu özelliklerini kaybettikleri görülmüştür. Lefkoşa'da sur içinde yer alan ve 1896 yılında geleneksel malzeme ve yapım teknikleriyle inşa edilerek günümüze ulaşmış nadir örneklerden biri olan Samanbahçe sosyal konut yerleşimi de, iklimle dengeli mimari niteliklerle inşa edilmiş olmasına rağmen, yıllar boyunca kullanıcı müdahaleleri ve yapılan restorasyon çalışmaları ile değişerek ilk inşa edildiği yıllarda sahip olduğu sürdürülebilirlik niteliklerini kaybetmiştir. Bu nedenle bu çalışmanın amacı, öncelikle özgün yerleşimin sahip olduğu iklimle dengeli ve enerji etkin niteliklerini ortaya çıkarmak ve bu niteliklerin konutların geçirdiği değişimle birlikte nasıl zarar gördüğünü ortaya koymaktır. Çalışmanın bir diğer amacı 21. yüzyıl konut kullanıcılarının gereksinimlerini de gözетerek, bu geleneksel konutlara iklimle dengeli ve sürdürülebilir özelliklerini yeniden kazandırabilmek için ne tür iyileştirmeler yapılabileceğini ve yerleşimi sürdürülebilir kılmak için ne tür önlemler alınabileceğini tartışmaktır.

Çalışmada ilk olarak mevcut literatürde yer alan geleneksel konutları iklimle dengeli nitelikleri açısından inceleyen çalışmaların bulguları özetlenmiş; daha sonra Samanbahçe Konutları

tarihsel gelişimi ile ortaya konulmuştur. Avlulu bina tipolojisinde ve sıra ev düzeninde inşa edilen bu konutların iklimle dengeli nitelikleri, yerleşme özellikleri, bina formu ve kabuğu incelenerek tanımlanmıştır. Çalışmanın yöntemi;

- konutların mevcut durumlarını tespit edebilmek ve kullanıcı memnuniyetini değerlendirebilmek amacıyla bir alan çalışması yapılması ve,
- elde edilen verilerin kullanılmasıyla gerçekleştirilen modelleme ve simülasyonlar yardımıyla mevcut durumda gerçekleşen ısıtma, soğutma ve aydınlatma yüklerinin belirlenerek değerlendirilmesi

şeklinde iki aşamadan oluşmaktadır.

Alan çalışması ile kullanıcıların konutlara yaptıkları müdahaleler saptanarak beş farklı kategori saptanmıştır. Örnek durum 1 Samanbahçe Konutları'nın hiç değişiklik yapılmamış özgün halini, örnek durum 2 konutların avlusunun yarı yarıya kapatıldığı, örnek durum 3 avlunun dörtte üçünün kapatıldığı, örnek durum 4 avlunun tamamen kapatıldığı ve örnek durum 5 ise bina formunun özgün halinin korunduğu fakat UNDP'nin yaptığı restorasyon ile bina kabuğunun değiştirilmiş halini temsil etmektedir. Bu beş farklı kategori simülasyon motoru olarak bütünleşik bir simülasyon programı olan ve dinamik bir hesaplama yöntemine sahip olan "Design Builder" ile modellenerek ısıtma, soğutma ve aydınlatma yüklerinin enerji etkinliği açısından etkileri karşılaştırılmıştır. Ayrıca kullanıcılarla yapılan anket çalışması ile kullanıcıların konutların günümüzdeki durumlarından, iklimsel ve görsel konfor koşulları açısından memnuniyet dereceleri saptanmaya çalışılmıştır. Bu çalışmanın kabulleri doğrultusunda beş farklı örnek durum karşılaştırıldığında elde edilen sonuçlar şöyle özetlenebilir:

- İncelenen örnek durumların hiçbirinde soğutma yükleri oluşmamıştır. Örnek durum 2, 3 ve 4'de avlu boyutları küçülerek binanın alanı ve hacmi arttığı ancak saydamlık

oranları aynı kaldığı için yaz boyunca alınan güneş ışıını miktarı azalmakta dolayısıyla soğutma yükleri de azalmaktadır. Bina kabuğunda kullanılan termal kütlesi yüksek geleneksel malzemelerin, özellikle 50 cm kalınlığındaki kerpiç duvarların, binalara gelen güneş ışıınımlarını azaltan dar sokakların ve avlu boyutlarının küçülmesiyle birbirine yaklaşan avlu duvarlarının yol açtığı gölgelenmenin bu sonucun elde edilmesinde etkili olduğu düşünülmektedir.

- Isıtma ve soğutma yüklerinin belirlenmesinde, sadece binanın toplam taban alanı değil, ısı geçişinin gerçekleştiği bina kabuğunun tüm alanı ve bu kabuğun çevrelediği bina hacmi de göz önünde bulundurulmalıdır. Dolayısıyla bina kabuğunun toplam alanının binanın toplam hacmine oranının (A/V) azalması yıllık, m² başına düşen ısıtma, aydınlatma ve toplam yüklerin de azalmasına yol açmıştır.
- Cephelelerdeki saydamlık oranı ve bina formunun A/V oranı binalarda oluşan toplam enerji yüklerini belirleyen temel parametrelerdir. Saydamlık oranı doğrudan güneş ışıınımlı kazancını dolayısıyla ısıtma ve soğutma yüklerini etkilemektedir. Bu nedenle avlunun boyutlarında yapılan değişiklikler A/V oranını da değiştirdiği için binaların toplam enerji yüklerini etkilemiştir.
- Gece ve gündüz kullanımı birarada düşünülerek oluşturulan anket soruları yardımıyla elde edilen anket

sonuçlarına göre, tamamıyla kapatılan avlular doğal havalandırma için bir engel oluşturmakta, nem seviyesini arttırmakta ve doğal ışıının iç mekanlara girmesini engellemektedir. Dolayısıyla konut sakinlerinin yaptıkları değişimler konutların ısısal ve görsel konfor koşullarını olumsuz yönde etkilemektedir.

Bu çalışmada, bina formunun bir bileşeni olan avlunun, konutların iklimle dengeli ve sürdürülebilir niteliklerinin korunması açısından önemi vurgulanmıştır. Bu nedenle konutların yeniden bu nitelikleri kazanabilmeleri için öncelikle avlularının özgün biçim ve boyutlarının korunması gerekmektedir. Bu hedefe yönelik olarak, konutların işletilmesinden sorumlu olan Evkaf Vakfı kurallar koyarak kullanıcıların konutlara müdahalesini engellemeli ve böylece konutların özgün halinin korunmasını sağlamalıdır. Konutların büyüme imkanı olmadığından kalabalık olmayan ailelerin bu konutlarda ikamet etmesini sağlamak, mekan genişletmek adına yapılabilecek değişimleri önlemek amacıyla alınabilecek tedbirlerden biridir. Ayrıca kullanıcıların alternatif enerji kaynaklarının kullanımı açısından bilinçlendirilmesi uzun vadede yerleşimin sürdürülebilirliğinin sağlanabilmesi açısından önemlidir. Son olarak bu çalışma iklimle dengeli niteliklerin hem geleneksel konutlara yapılacak herhangi bir müdahalede, hem de yeni inşa edilecek konutlarda gözetilmesi ve korunmasının sürdürülebilirlik açısından önemini ortaya koymuştur.