Occupant interaction with the interior environment in Greek dwellings during summer

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ABSTRACT: User behaviour significantly affects energy consumption simulation estimates, which can consequently influence architectural design decisions at an early stage. Different regional behavioural patterns could, therefore, hinder the applicability of certain architectural and environmental strategies. Through questionnaires analysis and field studies, this study investigates the pattern use of manual control of windows, shading and air condition units, in residential buildings in Greece, during summer. Initial findings of the analysis indicate significant interaction of Greek residents with the building shell, in their effort to maintain comfort.

Keywords: comfort, occupancy

1. INTRODUCTION

Building occupants interact with the building shell and its systems in order to satisfy their needs for comfort. This interaction can either benefit the utmost from the sustainable design techniques of the building or result in higher energy consumption due to lifestyle choice. It is, therefore, important to take occupant interaction with the interior environment into account when designing buildings. For example, different building construction techniques may be inconsistent with regional behavioural patterns.

The common practice of highly energy-efficient buildings promotes minimum interaction of the occupant with the building shell, while according to Leman and Bordass [1] people become more tolerant when they are able to control their environment. However, there is little reported on the subject from Greece, especially in residential environments.

In most Greek dwellings natural ventilation is used throughout the year, while the use of air conditioning, although limited, is rapidly increasing [2]. In this context, the present study investigates occupant behaviour in Greek dwellings and apartments in summer, through subjective surveys (questionnaires) and field studies. The aim of the study is to analyse the pattern use of manual control of windows, shading and air condition units, with the aim of correlating this pattern with indoor and outdoor conditions in a later phase of this research.

2. RESEARCH METHODS

The climate in Greece is typical of the Mediterranean climate: mild and rainy winters, relatively warm and dry summers and, generally, high solar radiation throughout most of the year. In terms of climatology, the year can be broadly divided into two main seasons: the cold and rainy period lasting from mid-October until the end of March, and the warm and non-rainy season lasting from April until September. The hottest months in Athens (longitude: 23.7, latitude: 38, Greek climatic zone B), are July and August, with monthly average temperatures of 27.5°C. The annual average temperature is 18.5°C, which makes this city one of the warmest in Europe [3]. In combination with the dense urban grid, the satisfaction of high cooling load is particularly difficult.

The study consists of two parts: a) subjective surveys (questionnaires) and b) field studies. The study was conducted in the summer (July to September) of 2010, using samples of respondents and dwellings from the four climatic zones of Greece.

2.1. Questionnaires

Greek residential building stock is concentrated mainly in cities, where thermal comfort during summer is a challenge due to the dense urban grid, thus, a sample of respondents scattered throughout cities all over Greece was used. The connection to the sample was produced by university students coming from different parts of the country.

The questionnaires were delivered to the subjects either in a hard copy or in a digital format by email. The subjects were given one week to fill in the questionnaire, which aimed to investigate subjective sensation, preference and satisfaction with regard to the indoor environmental conditions and highlight patterns of occupant behaviour concerning a typical summer day and not the day of the survey.

The questionnaire was divided into ten sections: building information, window size, ventilation, IAQ, view, shading, use of daylight and artificial lighting, thermal comfort, use of cooling systems, behavioural patterns in using various controls and their efficacy on a typical summer day. It was a comprehensive questionnaire to facilitate a better insight into the occupants’ interaction pattern with the building shell and their level of satisfaction with the current indoor environmental conditions. In order to measure sensation, satisfaction and preference either a five-point scale ranging from (-2) to (+2) with neutral (0) in the middle, or a seven-point scale from (-3) to (+3) with neutral (0) in the middle was used. For example, for thermal preference the five-point scale was as follows: much cooler (-2), a bit cooler, no change (0), a bit warmer and much warmer (+2), while for...
humidity sensation, the seven-point scale was as follows: very dry (-3), dry (-2), almost dry (-1), neutral (0), slightly humid (+1), humid (+2), very humid (+3).

Of the questionnaires distributed, 109 have been returned. The length and the complexity of the questionnaire probably caused some difficulties to the respondents.

2.2. Field studies

In addition to the questionnaire analysis, short term field studies were carried out in a number of houses in four climatic zones of Greece.

Window status, shading control, occupant behaviour, indoor (temperature, relative humidity) and outdoor climatic conditions were monitored, in an attempt to investigate how Greek houses and residents behave during summer.

Monitoring was carried out in August and September 2010. Temperature measurements were taken indoors and outdoors at time intervals of 1 min. Greek families typically spend most of their time in the living room, which is consequently the space where people interact most with the building envelope, so the analysis focuses on the living room conditions.

A temperature and humidity data logger was used in living rooms and on balconies to measure the indoor and outdoor thermal conditions. The data loggers were placed at the centre of each room at a height of approximately 85cm. The data logger on the balcony was put in a place protected from direct sun, rain and wind, and it was not in contact with any other surface. The behavioural pattern of changing the state of windows, shading and cooling systems has been derived from the residents’ notes on their daily routine, as declared.

3. RESULTS AND DISCUSSION

3.1. Location, building types, envelope characteristics and sample profile

The survey sample consists of 44 male and 65 female participants (40.4% and 59.6% respectively). Approximately 50% of the participants are between 40 and 60 years old, 42% is in the 20 to 40 year old age group and only 8% are over 60. The respondents come from 14 cities of Greece distributed across all four different climatic zones of the country (Zone A: 14.7%, Zone B: 24.8%, Zone C: 39.4%, Zone D: 21.1%).

The predominant (64%) type of residence of the survey sample is an “apartment”, which is representative of Greek urban reality, while 19% of the respondents live in a “detached house” and 17% in a “house in contact with other buildings”. The majority (approximately 60%) of the residences are located in the city centre (48% apartments, 7% houses in contact with other buildings, 5% detached houses), whereas the remainder are located in the suburbs (33%) and in the countryside (7%).

Building age is an important factor as it may be an indication of the construction type. For example, a Greek building over 30 years old has no thermal insulation, as the regulation for thermal insulation in Greece was not established until 1979. The age of residences in the sample is distributed as follows: 34% less than 10 years old, 45% between 11-30 years old and 21% over 30 years old.

The significant majority (96%) of the participants’ houses are conventional Greek constructions, i.e. concrete post and beam construction with cement plastered and brick in-fill walls. The “Other” category (4%) included a mix of conventional construction with steel or a mix of stone construction with timber.

66% of the subjects stated that the period they have lived in their current house is “more than 5 years”, 27% chose “between 1-5 years” and only 6% “less than a year”. This distribution suggests that the participants have already formed a behavioural pattern for the house they live in, so their responses have a certain significance.

Natural ventilation was used for IAQ in all survey residences, while some occupants owned AC units which were used for cooling.

3.2. Respondents’ evaluation of their indoor environmental conditions

Occupants were asked to evaluate their indoor environment during summer by expressing sensation, level of satisfaction and preferences for certain conditions. Fig. 1 shows that occupants, on average, are neither satisfied nor dissatisfied with their indoor temperature during a typical summer day. The standard deviation of the sample though, is large, indicating a variety of satisfaction levels among the occupants. The subjective temperature sensation, on average, is neutral to warm, while all of the respondents in the survey prefer to be a bit cooler or much cooler. Concerning the indoor air quality the sample is satisfied, but the standard deviation of the humidity sensation vote (close to neutral on average), indicates some complaints about humid, mainly, or dry air. Even though all the occupants are not dissatisfied with the window size, they would prefer a larger one. The daylight levels, on average, are perceived as acceptable to high, but the standard deviation of the sample is large, indicating various levels of daylight. Similar comments apply to view satisfaction, while noise levels in residences appear to be acceptable to low.

The main observation is that, on average, the participants characterise the majority of the indoor environmental conditions, as neutral, with a slight trend towards good, but a large standard deviation is noticed. Moreover, it is clearly stated that all the occupants would prefer to feel “cooler” to “much cooler” during a typical summer day, even though their mean temperature satisfaction vote is close to acceptable. The mean overall satisfaction vote of the participants for the house as a whole (taking into account any possible parameter and not only indoor environmental conditions) tends to be “slightly satisfied”.

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3.3. Reasons for occupant interaction with windows

As residential buildings in Greece are, on average, naturally ventilated, the control of windows and balcony doors is the main way to achieve thermal comfort and good IAQ during summer.

Hence, the window opening type plays an essential role in the ventilation rates, and consequently in the user behaviour. A wide variety of window opening types is available. Sliding and side hung windows are the most common type used in Greece. In the survey, 59% of the participants use sliding windows, while 34% side hung windows. The usual percentage of window opening during summer is 50-59% (43% of responses) and 100% (24% responses). As it was not clearly defined in the question whether the percentage of opening refers to the whole glazing surface or to the feasible opening depending on the window opening type, some of the responses of 50% opening may correspond to the sliding windows, indicating maximum use of the feasible opening area of the window.

As fig. 2 shows, the primary (67%) reason for opening a window during summer is the improvement of IAQ. A secondary reason is the decrease in indoor temperature (32%), while only 1% voted for acoustical connection to the external environment. The results reflect the importance of good IAQ to the occupants. On the other hand, occupants who prefer night cross ventilation (31%), are more interested in improving thermal comfort (28%) than IAQ (4%). Therefore, the predominant pattern derived from the study is daily use of cross ventilation during the morning to improve IAQ.

3.4. Ventilation

Regarding the possibility of cross ventilation, 79% reported that this is possible, while 21% not. Where cross ventilation is possible, it is commonly used daily (72%), or at least “often” (4-6 times/week).
3.5. Frequency of window alteration depending on the time of day

Fig. 6 presents the frequency of altering the window state during a typical summer day and how this behaviour is distributed across different times of the day. A strong interaction of occupants with windows is noticed, as 45% of the sample change the window state “2-3 times/day”, 30% “more than 3 times/day” and only 16% “1 time/day”. Thus, modern Greeks still interact considerably with the building shell, trying to adapt to the changing environmental conditions throughout the day. There is a tendency for occupants to change the window state mostly when they wake up (31%), and slightly less when they spend many hours in the house (26%). A smaller portion of the participants (19%) alter windows when they leave the house. On the other hand, there is a dependency between the frequency of window use and the time of day. Therefore, the majority of participants that control window state 2-3 times/day, interact with the windows mainly when they spend many hours in the house and not in the morning, as the largest part of the sample reported. Consequently, it is concluded that the amount of time spent at home affects the time of day that occupants interact more with the windows.

3.6. Use of shading – reasons and pattern of use

According to the survey participants, the most important reason for opening the shading is to facilitate room ventilation (42%), followed by increasing daylight levels (39%) and keeping visual connection with the external environment (10%). A small proportion of the subjects (7%) stated that they never open the shading during summer. On the other hand, the predominant reason for closing the shading is to achieve a decrease in indoor temperature (69%), followed by a decrease in daylight levels (12%). Other secondary reasons are “glare protection” and “more privacy”. Therefore, it is noticed that opening of the shading is determined by IAQ, as is window opening, while the closing of shading is determined by indoor temperature, as is the case of window closing.

The frequency pattern of shading use is similar to that of window use. The majority of the occupants (49%) change shading state 2-3 times/day, 26% once per day, 13% 1-3 times/week, 9% rarely or never alter it, but only 4% control the shading “more than 3 times/day”. This 4% is significantly smaller than the corresponding 30% concerning window use. So even though the majority of the occupants control both windows and shading 2-3 times/day, the frequency of interaction with windows is considerably higher in total.

Fig. 7 shows the distribution of the frequency of shading use according to the time of day. People who adjust the shading 2-3 times/day do it mostly when they wake up (18%) and secondly when they spend many hours at home (14%). In contrast, people who stated that they change the shading once per day, mainly do it when they spend many hours at home. Occupants that interact most with the shading (only 4% of the sample), more than 3 times/day, do it mainly when they return home (2%). Correspondingly, results for the time of day that people control most their shading, irrespective of the frequency of shading use, show that 31% of occupants control the shading when they spend many hours at home, and 26% when they wake up. Most of the sample (71%) shade, the 75-100% of the window surface.

3.7. Cooling systems

Regarding cooling systems, 70% of the survey subjects reported that they have AC in the house,
approximately 45% have a type of fan and only 8% do not have a cooling system (fig. 8).

Fig. 9 shows that July and August are the months that cooling systems are most in use. As expected, August accounted for the largest percentage of use for both AC and fans.

Early afternoon hours (13:00–17:00) seem to be the time of day with least thermal comfort as the majority (68%) of the subjects use cooling systems during this period (fig. 10). The following hours (17:00-20:00) account for 41% of the cooling use, while there is a significant proportion of the occupants (28%) that make use of cooling systems during the night (24:00-08:00).

Fig. 11 describes the relationship between frequency of night ventilation use, subjective sensation of humidity of the air and use of AC during night hours. The most interesting remark is that 50% of the occupants that stated they use night ventilation daily also use AC during the night. An explanation might be given by their sensation vote for humidity of the air, which is mainly perceived as neutral (33%). These subjects simultaneously use AC during the night to improve indoor temperature and night ventilation to maintain IAQ.

According to fig. 12, the mean temperature set in AC is 24,53°C (STD= 2.56), while the mean highest temperature at which they are willing to set AC in order to save energy, is 26,33°C (STD= 1.88). The difference between the means is only 1.8°C which indicates that survey subjects are not ready to compromise their comfort in order to save energy.

4. MONITORING

In addition to the questionnaire analysis, a short term monitoring study measuring air (accuracy ±0.5°C (-20 to 50°C)) and surface temperatures, relative humidity and illumination levels was carried out, during summer conditions, in a number of houses. To achieve this, small sensors were placed around the house for a period of at least two days. The scope of this work was to verify the results of the questionnaire analysis, comparing the responses with the interior conditions when some change in openings occurred.

The example below presents results from a naturally ventilated 80 m² flat in Greek climatic Zone B, built during 2000 (fig. 13). The building is well protected by other buildings to the south and north with east/west facing openings, shaded by large balconies.

![Figure 13: View of the house (Source: Bing maps)](image)
The graph in fig. 14 presents two successive days with the first having all openings closed and the residents absent, while in the second openings are modified by occupants. The indoor temperature remains steady at 28.3°C when the flat is unoccupied with openings and shutters closed - an expected behaviour, since the building has high thermal mass and the internal and external gains remain stable. With the arrival of the occupants, the windows and shutters are opened and ventilation thus reduces the indoor temperature. However, this reduction is quite small (~1°C), despite cross ventilation being used, as a consequence of the building’s heavyweight construction and the protection provided by adjacent buildings and large balconies.

Multi-storey apartment buildings in a row are the typical type of residence in Greece. A dense urban grid comprised by this type of building decreases the effectiveness of natural ventilation to provide thermal comfort. Consequently, the pattern described in fig. 14 might explain the simultaneous use of AC units and openings during the night, which arose from the questionnaire analysis, since natural ventilation alone cannot significantly decrease temperature on calm days.

5. CONCLUSIONS

This study presented some of the initial findings of a questionnaire and field study analysis on the occupant interaction with the interior environment in Greek dwellings during summer.

On average, the participants characterise the majority of the indoor environmental conditions, as neutral, with a slight trend towards good, but a large standard deviation is noticed, probably because of the relatively small size of the sample. Even though the mean temperature satisfaction vote is close to acceptable, all the survey occupants prefer to feel “cooler” to “much cooler” during a typical summer day.

It has also been found that most occupants control window state and shading 2-3 times/day. Improvement of IAQ is the main reason for window opening, while facilitation of room ventilation constitutes the main reason for opening the shading. Prevention of overheating is the principal reason for closing windows or shading. The majority of the occupants control both windows and shading 2-3 times/day, but the frequency of interaction with windows is considerably higher in total.

Survey participants prefer to use cross ventilation daily, during the morning, to improve IAQ, while daily use of night ventilation is preferred too.

Use of AC is increasing in Greece, with 70% of the survey subjects owning AC units in the house. The paradox is that these subjects simultaneously use AC during the night (to improve indoor temperature) and night ventilation (to maintain good IAQ).

Further research is needed, however, to verify the preliminary results of this survey. The difficulty of questionnaire surveys and field studies, especially in residences, in Greece should be taken into account for further research.

Because of the lack of previous studies for occupant behaviour in residences in Greece, the results of this study may form a foundation for the monitoring of the evolution of user behaviour in Greek houses, as architectural thinking and practice change. They could also form a basis for a better understanding of the interaction of the resident with the interior environment, which can help improve energy simulation estimates. It could also be investigated whether different construction techniques (such as mechanically ventilated low thermal mass dwellings) are affected by the Greek pattern of occupant behaviour.

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7. REFERENCES

