Users' perception of comfort and well-being in university buildings

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ABSTRACT: This paper analyses the overall environmental conditions in selected university buildings of the National Technical University of Athens, Greece according to the perception of their users. The analysis is based on questionnaires distributed to the users of each building, working both in conventional and open-plan office spaces. During the same period, measurements of air temperature, relative humidity and daylighting levels were conducted in representative spaces of these buildings.
The use of questionnaires aimed at obtaining subjective information concerning the whole range of internal comfort conditions (thermal, visual, acoustic and air quality). Furthermore, the analysis of the accumulated data also led to crucial observations concerning the users' "environmental conscience" on issues such as energy conservation, recycling, etc. as contrasted to their views and wishes on personal comfort expressed by daily use patterns in their own work environment.

Keywords: university buildings, users' perception of comfort, questionnaires

1. INTRODUCTION

Public buildings in Greece often exhibit high energy-consumption patterns. This also applies to educational buildings of all levels and is, in most cases, directly related to several bioclimatic parameters in their design and construction, in addition to obsolete maintenance and control features. Besides excessive use of conventional energy sources for heating, cooling and lighting and the resulting environmental impact, such parameters can also have considerable influence on the comfort and well-being of people who work in these buildings.

Monitoring of air temperature and daylighting levels can provide valuable information concerning thermal and visual comfort conditions within buildings, but can give us no insight as to the users' perception of comfort and well-being. This paper attempts, therefore, to present selected issues of overall comfort conditions in office spaces of university buildings, according to their users, based on a questionnaire distributed to a typical sample of the University community.

2. DESCRIPTION OF THE STUDY

2.1 The overall project

The project, of which this study forms part, has been partly supported by EEC SAVE and Thermie programs. It is based on the analysis of representative case studies of University buildings in Greece in terms of their environmental performance.

Three buildings of the National Technical University of Athens Campus at Zografou were thus selected, on the basis of their age, type, scale, morphology and construction features: a) the Rural and Surveying Engineering Building, a typical old generation small scale, compact classroom building, b) the Chemical Engineering Building, a representative new generation, large scale classroom and laboratory building, and c) the Administration Building, a modern, medium sized office building, unique on campus due to its function.

For each building selected, the study consisted of three phases: a) analysis of environmental performance b) diagnosis, and c) scenarios of retrofitting interventions. The analysis included measurements of environmental conditions and distribution of questionnaires to representative users. of each building. The authors have published the results of air temperature and daylighting measurements in earlier papers, while a summary is included in the following section.

The scenarios proposed included energy conservation and bioclimatic features, which have been integrated to the retrofitting process. These interventions consist of standard as well as innovative r.u.e. and r.e. systems, combined in order to achieve a considerable improvement of thermal and visual comfort for users by synergy effect, and reduce fossil fuel and electricity consumption -hence the buildings' environmental impact. For more, see [1] to [4] below.

2.2 The questionnaires

The questionnaires comprised of five different sections, presented in Table 1. They were distributed to building users electronically (via e-mail) or personally (in hand-outs) as shown in Table 2.

Table 1: Structure of the questionnaires

A. General information
▪ Age and Sex of the user
▪ Floor level and orientation of the office space
▪ Number of windows
▪ Distance from nearest window.
▪ Number of people in the same office
B. Environmental conditions
▪ Thermal comfort
▪ Air quality
▪ Temperature variations
▪ Air draughts
▪ Air moisture and freshness
▪ Lighting (daylighting and artificial lighting)
▪ Noise
C. Other elements in the working environment
▪ Ability to control / adjust air temperature
▪ Ability to control / adjust ventilation
▪ Ability to control / adjust lighting conditions
▪ Cleanliness
▪ Presence of smokers in the same office space
D. User-related questions
▪ Possible health problems (e.g. asthma, allergies)
▪ Smoking habits during working hours.
E. Comments

Table 2: Details on questionnaire distribution

Rural and Surveying Engineering Building	
Dates of distribution:	01-05/07/2002 and 25-29/11/2002
Mode of distribution:	E-mail
Number of questionnaires:	Allbuilding users(~68)
Administration Building	
Dates of distribution:	31/10-4/11/2002
Mode of distribution:	Hand-outs
Number of questionnaires:	200
Chemical Engineering Building	
Dates of distribution:	25-29/11/2002 and 2-6/12/2002
Mode of distribution:	E-mail
Number of questionnaires:	Allbuilding users(~85)

3. DISCUSSION OF THE RESULTS

The completed questionnaires were analysed statistically, while processing of the results involved the creation of numerous tables and charts. Even though the scale of the study was relatively limited, the detailed presentation of the results for every building was extensive, as it comprised of an analysis of all data assembled, only a small part of which is discussed in this paper. The discussion focuses on issues of thermal and visual comfort, as well as ventilation and air quality. Furthermore, an attempt is made to discern the users' “environmental conscience” concerning these issues.

3.1 The Rural and Surveying Engineering Building

This building, constructed in the ‘60s, is representative of “old generation” University buildings in Greece, in terms of design and construction. It has a floor area of 8550 sq. m. and N-S orientation with a marked differentiation of the two main facades in terms of openings. It is composed of classrooms, laboratories and staff offices of small to medium size. (Fig.1) and has single glazed windows and no insulation.

Air temperature levels are high and rather stable, due to the high thermal mass of the building, and can only be controlled by window opening. Daylighting levels can be very low in internal corridors while glare is a problem in Southern offices.

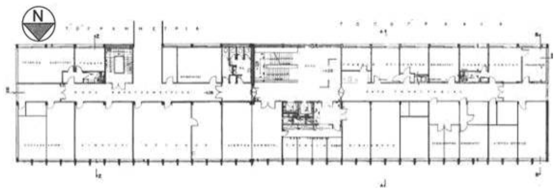

Figure 1: Typical floor plan of the building.

3.1.1 Thermal comfort

The majority of users (64%) rated thermal comfort conditions in their offices as “warm” or “hot”. The answers were found to be independent of the orientation of office spaces and were mainly attributed to external weather conditions (early July).

It is interesting to compare thermal comfort and air temperature ratings. One would expect that the number of people who judged thermal comfort conditions as "hot" would also characterise air temperature as "unpleasant". Nevertheless, this wasn't the case, and only 28% of the users did so (Fig. 2) probably due to their adaptability to warm weather.

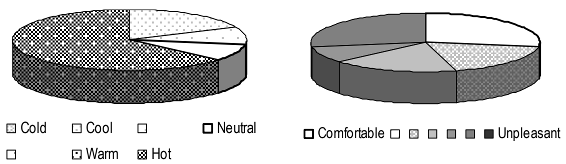

Figure 2: Summer thermal comfort ratings.

A fairly large percentage of the users noted that they could fully or almost fully (37% and 9%, respectively) adjust air temperature in their office space according to their needs. (Fig. 4) As these answers were cross-checked with those concerning the presence of auxiliary heating and/or cooling devices in individual offices, it turned out that this was in fact possible through the use of such devices, namely split-type air-conditioning units.

3.1.2 Visual comfort

As far as lighting conditions are concerned, the answers collected reveal no significant problems. (Fig. 3) What is more, a large percentage of the users noted that they could fully or almost fully control lighting in their work-station. (Fig. 4) This is due to the fact that this building mostly comprises of small office units, with individual windows and autonomous lighting. Nevertheless, as 36% of the users reported that they could not control lighting conditions at all, or almost at all, it was deduced that these answers refer to the absence of daylight control in southern office spaces, where cumbersome external shutters are the only means of shading.

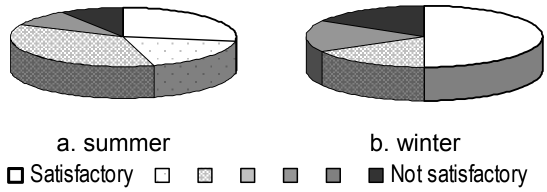

Figure 3: Overall visual comfort.

3.1.3 Ventilation

Due to basic design parameters, most users have direct access to windows in their work-stations, so that they can benefit from natural ventilation. This explains the high percentages of users who can fully (36%), or almost fully (55%) control ventilation in their space.

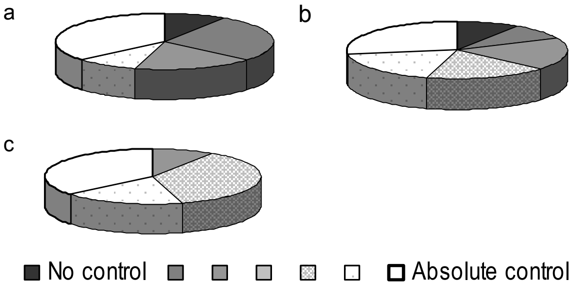

Figure 4: Ability to control a. air temperature, b. lighting and c. ventilation.

3.1.4 Air quality

An important percentage (73%) of users considers air quality in the building to be unacceptable to barely acceptable (Fig. 5). This may be due to the fact that the design of typical office spaces does not allow for cross-ventilation of individual units.

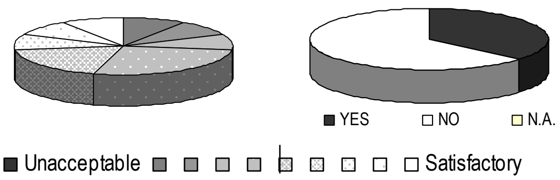

Figure 5a: Rating of air quality during the summer.
Figure 5b: Number of people who smoke in their work-space.

Another important parameter of air quality is smoking. Based on the questionnaires, it was seen that most smokers do so in their work-space. The only reason why this fact does not create serious air quality issues is that office spaces are used by one or two persons only, thus affecting significantly fewer people than in the case of open-plan office spaces.

3.1.5 Other issues

Concerning noise levels and acoustic comfort, users judge the overall performance of this building as satisfactory.

3.2 The Chemical Engineering Building

This building, constructed in the '80s, but designed in the 70's, is representative of modern University buildings in Greece in terms of design and construction. It can be divided into three equivalent parts, each formed of one laboratory unit on the North and one office unit on the South of a courtyard, joined by teaching, research and administration spaces on the East and West sides. The building has a total covered surface of approximately 30000 sq. m. and a heated surface of only 12000 sq. m. Its main axis runs North to South and is accentuated by two six-metre wide corridors on either side of the courtyards. (Fig. 6)

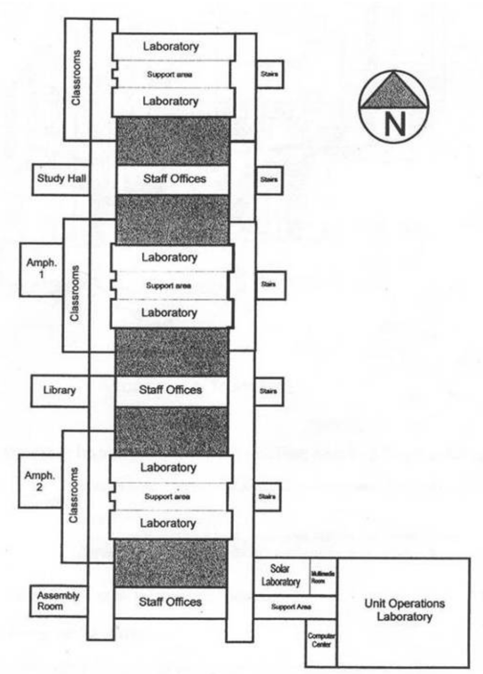

Figure 6: Schematic diagram of the building.

In spite of high thermal mass, low air temperature levels in the winter are caused by the northern orientation of many spaces and extensive unheated corridors. Daylighting levels are low in many circulation areas and north-facing office spaces.

3.2.1 Thermal comfort

Most users (48%) rated thermal comfort conditions at the time of the interview as "relatively cool" to "cold" (Fig. 7). As these answers were related to the orientation of each space, it turned out that thermal comfort conditions were rated as "neutral" to "hot" in office spaces oriented to the South and "neutral" to "cold" in those oriented to the North.

Due to its design, north-facing offices form the majority in this building. They are located in single-loaded office units, where corridors face South, and have increased thermal losses as expected.

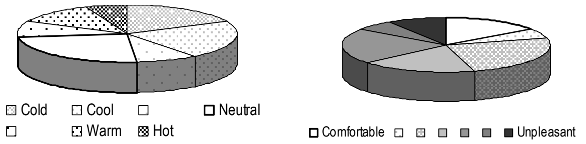

Figure 7: Thermal comfort ratings, in the winter.

Concerning thermal comfort during the heating and cooling periods, only qualitative conclusions can be drawn from the comments of the users. It can be seen that, for the heating period, the hours of operation of the central heating system (8:00-14:00) do not coincide with the hours of operation of most laboratories and offices (until 17:00-18:00). This creates the need for auxiliary heating systems, which are usually very energy-consuming. On the other hand, the use of heavy machinery in the laboratories adds significant thermal loads to the spaces, making the need for auxiliary cooling inevitable in the summer.

More than half of the users (54%) replied that they rely on split-type air-conditioning units for auxiliary heating and cooling. The cross-check of the questionnaires revealed that these people also replied having complete control over air temperature in their office spaces. On the contrary, the persons who rely exclusively on the central heating system for heating and on windows for cooling, reported that they cannot control air temperature in their offices.

3.2.2 Visual comfort

As far as daylighting is concerned, it was noted that most work-stations are situated in the immediate vicinity of windows (0-3 m distance).

In general, answers concerning visual comfort conditions revealed no significant problems, since for 20-30% of the users lighting conditions were referred to as "ideal, stable, uniform", or "all in all satisfactory". (Fig. 8) This is due to the fact that no distinction is made in the questionnaire between natural and artificial lighting. As lights in most spaces stay on throughout the day, even on days with clear sky and adequate daylighting levels, it is clear that all answers refer to the combined effect of natural and artificial lighting, with no concern for actual daylighting levels.

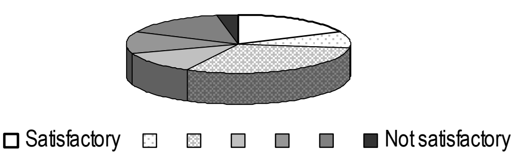

Figure 8: Overall visual comfort rating.

Concerning lighting controls, the answers do not reveal significant problems (Fig. 9). Nevertheless, the artificial lighting system does not allow for individual adjustments in different work-stations. As one user eloquently wrote: "in order to have lighting in an area no larger than 10 sq. m., electric lights in a space of 140 sq. m. have to operate (...)".

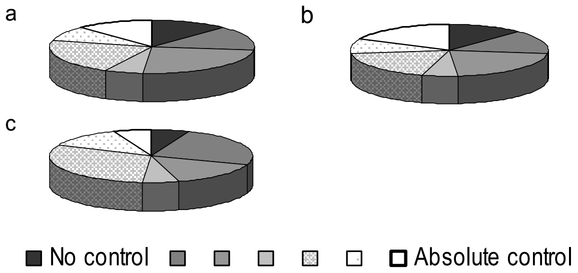

Figure 9: Ability to control a. air temperature, b. lighting and c. ventilation.

3.2.4 Air quality and ventilation

Due to its function, this building has an increased demand for continuous and efficient ventilation in order to improve air quality, which is often deteriorated by chemical processes.

This is therefore the most pressing environmental problem, as 52% of the users considered air quality in their office space to be "unacceptable", while 21% judged it as "barely acceptable" and only 27% as "satisfactory". (Fig. 10a)

As a contrast to the Administration Building, where smoking is the major cause of air quality deterioration, the number of smokers in this building is rather small (33%), and only 12% of them do so in their office spaces. (Fig. 10b) This is explained by the fact that many spaces are also laboratories, where smoking is forbidden for safety reasons.

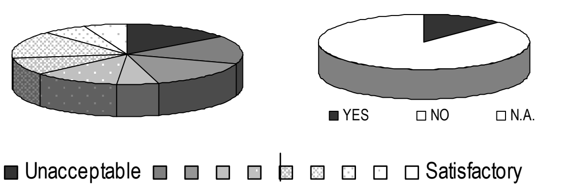

Figure 10a: Rating of air quality during the summer.
Figure 10b: Number of people who smoke in their work-space.

3.2.5 Other issues

The Chemical Engineering Building was the only one, where users made reference to recycling. Some users reported gathering paper, batteries, electrical equipment, and computer consumables on their own. Unfortunately, there are only a few bins for paper recycling in the N.T.U.A. Campus, of which none for aluminium, plastic, glass, batteries or computer consumables.

3.3 The Administration Building

The Administration Building (1987) shelters central administrative, financial and technical services of the N.T.U.A. It has an L-shaped plan, and three levels, with a total heated surface of 6876 sq. m. (Fig. 11) Many offices have open-floor plans, divided into smaller work stations through movable partitions, while the University Multi-Purpose Hall is also located on the ground floor of the building.

Due to its shape and access, the building has many facades, each treated differently in terms of morphology and openings. All windows are doubleglazed with aluminium frames, some of which are operable with fixed skylights and no external shading.

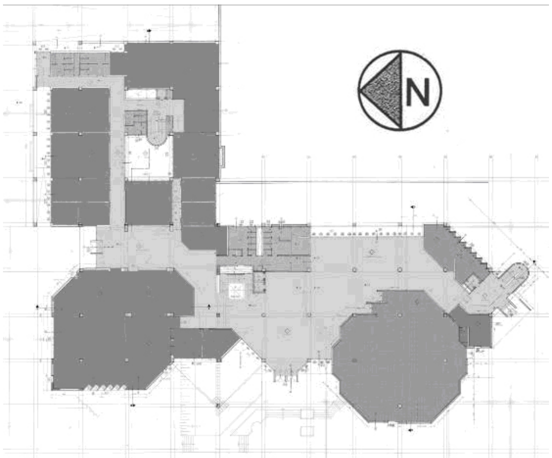

Figure 11: Typical floor plan of the building

In this building, most problems reported by the users concerning thermal comfort, ventilation, or acoustic comfort are related to the faulty design and operation of the central HVAC system, which has the following repercussions on comfort:

- Excessive heating during the winter and cooling during the summer
- No possibility of control of interior air temperature in individual office spaces
- No possibility of fresh air supply and adequate ventilation, when the system does not function
- Source of substantial noise during its operation in some office spaces

Daylighting levels are satisfactory, with the exception of some open-plan office spaces, while the Multi-Purpose Hall relies completely on artificial lighting.

3.3.1 Thermal comfort

Most people (45%) classified thermal comfort as "cool" and "relatively cool", while 38% answered that thermal comfort conditions in their office space at the time of the survey was “ideal”. (Fig. 12)

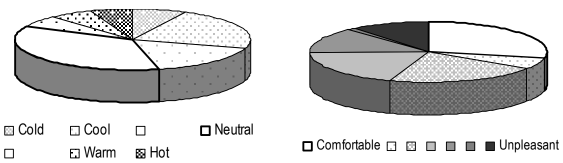

Figure 12: Thermal comfort ratings.

Since the query was conducted in October, when the heating system is not in operation and outside temperatures range between 15 and 18 °C, these results seem logical.

Although questions on thermal comfort were targeted to the period of the year, when the questionnaire was filled in, many users included remarks concerning thermal comfort conditions during cold and hot periods of the year, attributing extreme temperature levels to the operation of the HVAC system. These comments lead to the observation that apart from its high energy consumption, the incorrect operation of the HVAC system significantly deteriorates thermal comfort conditions during periods when heating or cooling is necessary.

Concerning air temperature, the majority of the users (65%) reported that they have no means of controlling it (Fig. 13). As a result, thermal comfort throughout the year largely depends on the correct operation of the whole HVAC system. Many users referred to the windows, as the only means of temperature control.

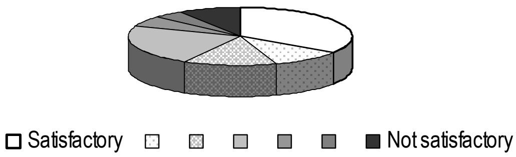

Figure 13: Overall visual comfort rating.

3.3.2 Visual comfort

As far as lighting is concerned, it appears that no significant problems exist, since Interior lighting conditions were characterised by the majority of the users (43%) as “ideal, stable, uniform” and “generally satisfactory”. Concerning lighting control, the answers provided are evenly distributed throughout the entire range of possibilities, from total control, to complete absence of it (Fig. 14).

The almost unanimous satisfaction concerning lighting conditions does not agree with the fact that in open plan office spaces, only few work-stations are situated near windows (Fig. 13). Therefore, it can be assumed that these answers refer to artificial lighting or the combination of artificial lighting and daylighting.

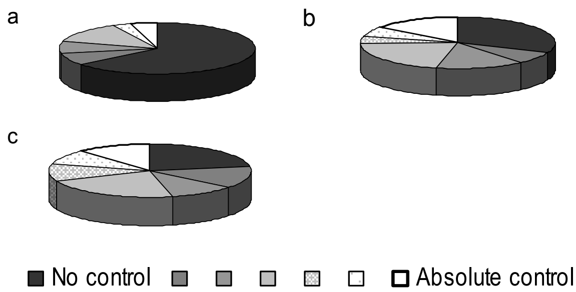

Figure 14: Ability to control a. air temperature, b. lighting and c. ventilation.

3.3.3 Ventilation

Although 32% of the users reported that they do not control ventilation in their office, an equal percentage reported the opposite. (Fig. 9) This is mainly due to the fact that ventilation of office spaces is controlled by the central HVAC system. As this system does not function during intermediate seasons (autumn and spring), windows are the only available means of ventilation. Unfortunately, many work-stations are situated very far from windows, while cross ventilation is not possible in most cases. What is more, users differ on their needs for ventilation as their positions with respect to windows vary.

3.3.4 Air quality

The questionnaires did not evoke significant air quality problems. Nevertheless, many employees (43%) reported the air to range from "neutral" to "heavy", suggesting problems of ventilation and fresh air supply in the building. This is due to the fact that during the intermediate seasons, when the HVAC does not function, the area of windows in relation to the area of the large office spaces is too small to adequately ventilate the spaces. What is more, many users consider air to be "relatively stuffy" and "with some odours", as this is related to the large number of people who smoke in their offices, as well.

The number of smokers in the building is relatively large (50%). Furthermore, many of these people (34%) admitted smoking in their office space, as there exists no space for smokers to use during breaks (Fig. 15b). As open-plan spaces are divided by means of light-weight, relatively low-rise partitions, the smoke circulates and eventually reaches everybody.

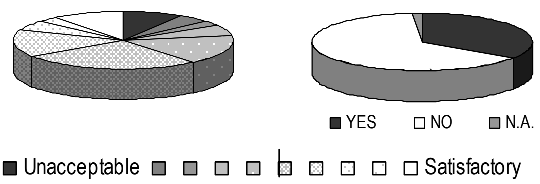

Figure 15a: Rating of air quality during the summer.
Figure 15b: Number of people who smoke in their work-space.

3.3.5 Other issues

It is interesting to note that in many questionnaires, the question concerning orientation of the office space was not answered or was answered wrongly. This is due to the fact that many work-stations are situated far from the windows and have no direct contact with outside conditions, including the movement of the sun.

4. CONCLUSIONS

This study revealed three equally significant issues.

Firstly, as thermal comfort conditions are directly linked to the operation of central heating systems, when these do not function properly, due to design or construction failures, thermal comfort conditions are significantly deteriorated. In these cases extreme dissatisfaction is expressed by the users as they feel they can have no control of this situation. In case this is allowed, additional environmental problems may be generated, as many users resort to auxiliary heating devices, mostly split-type air-conditioning units, which have significant energy consumption.

Secondly, the importance of air quality in the users' perception of comfort was pointed out. It is a unanimous demand that interior air should be maintained fresh and free of pollutants (tobacco smoke in all three buildings and chemical fumes in the case of the Chemical Engineering Building) at all times. Consequently, there is a need for sufficient and efficient ventilation, which the users prefer to achieve through "natural" means, namely windows or other openings rather than HVAC systems, and the buildings should offer this possibility.

Thirdly, since no distinction between daylight and artificial light was made in the questionnaires, it was noted that in all three buildings, lighting conditions were judged as satisfactory in terms of intensity, uniformity and stability, as users refer to the overall lighting levels, including artificial lighting. In-situ daylighting measurements in all three buildings revealed that in most office spaces lights stay on throughout the day, even if daylighting levels are sufficient to ensure visual comfort.

Although this may be due to insufficient shading or the presence of glare, this last issue also reveals a reduced environmental awareness on the part of the users, and raises questions concerning their behaviour towards heating and cooling, had it been possible to fully adjust them in their individual office spaces, according to their desires.

In fact, this general lack of "environmental conscience" is also revealed by the absence of organised recycling. In office spaces, where substantial quantities of paper and office consumables are rejected every day, only few people, on their own initiative, separate and recycle their office waste.

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