ANALYSIS OF ENVIRONMENTAL ASPECTS AFFECTING COMFORT IN COMMERCIAL BUILDINGS

by

Panagiota ANTONIADOU**, *Effrosyni GIAMA, and Agis M. PAPADOPOULOS

Department of Mechanical Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece

Original scientific paper
https://doi.org/10.2298/TSCI170921016A

Environmental aspects are of high priority for the identification and evaluation of the parameters that affect the design and construction of buildings. Their improvement in case of the existing European building stock while considering and maintaining the occupants' comfort sensation in high levels, is imperative for creating an environmental friendly building. The combination of those aspects can upgrade the indoor conditions leading to the creation of an appealing workspace where the well fair of the occupants is established. In this line of approach, an integrated evaluation of the indoor environmental parameters was conducted in office buildings, located in Thessaloniki, Greece, based on the occupants' comfort sensation. Main goal of the study is the determination of the existing correlations between the perceived comfort sensation and a variety of environmental parameters considered in building rating certification schemes. Those correlations can outline the weight of every aspect based on the occupants' view and also help the policy makers to accomplish the vision of an environmental sustainable, not only concerning the energy consumption but also the occupants, building.

Key words: *comfort, environmental aspects, Mediterranean region, office buildings, occupants' perception*

Introduction

Achieving environmental sustainability of both working and living areas is extremely important as it can affect the occupants' health and well-being. Despite the significant improvement of the energy performance of new buildings in the 1990 and 2000, the bulk of older, less efficient buildings, leads to an increase of the energy consumption by the building sector (38% of the total final energy) in order to establish the optimal thermal comfort and indoor air quality [1]. This highlights the potential for energy conservation without reducing, or probably even increasing, the occupants' comfort [2, 3]. In this framework, international standards (EN ISO 7730, EN ISO 15251) and European Directives (91/2002, 31/2010) have been issued over the last decades, emphasizing the importance of upgrading the occupants' comfort, increasing the buildings' energy performance and reducing respectively their energy consumption [4-7]. However, the implementation of the institutional framework faces certain difficulties as the vast majority of the European building stock dates before 1990 and only 16.7% was constructed from 1991 to 2010 [8]. In case of Greece, until today, only two regulations regarding the energy upgrade and the thermal insulation have been published [9, 10]. On the other hand, regarding comfort only the attainment of high satisfaction on each comfort parameter (thermal, visual,

* Corresponding author, e-mail: pantoniadou@auth.gr

acoustic and air quality) based on the respective international standards is established [10].The classification of Greek building stock is similar to the European one with 68% of the buildings were constructed before 1981 and hence prior to the introduction of the first thermal insulation regulation [11, 12].There is, therefore, a profound need to evaluate the indoor environment conditions of existing buildings, and especially of office buildings, as they affect the occupants' concentration and productivity levels, as well as their health and well-being [4]. In order to achieve the indoor conditions' evaluation, research shows that in situ monitoring is needed [13, 14]. Still, an integrated evaluation can only be achieved when not only thermophysical parameters are determined, but also a personalized research is conducted [15, 16].

The evolution in this scientific discipline can be determined based on a series of literature reviews conducted over the years regarding thermal comfort. In detail, the initial update of the developed methodologies regarding the traditional perception of thermal comfort [17-21] has developed nowadays into a multiparameter perception and determination of comfort [22-24]. In this case, more parameters are taken into consideration such as individual characteristics and the occupants' perception. Therefore, further analysis on the buildings' evaluation and occupants' interaction is appropriate.

Moreover, another aspect that should firmly be considered, is the environmental, which is in depth included and evaluated in the building rating systems, which are environmental and management tools that aid in focusing on the construction sector and aiming at sustainability, as well as at economic and social benefits. Rating systems for buildings have incorporated the expertise and knowledge from environmental methodologies, decision making and management tools, which have been used in other productive sectors and were therefore influenced by those.

In this sense, rating systems are scoring systems designed to evaluate new and existing buildings based on a selected standard of assessing environmental performance. The most popular certification schemes based on the number of certifications accredited are building research establishment environmental assessment method (BREEAM) [25]: It is a European rating system developed in the UK, but available and applicable to any other country, with measurable evaluation characteristics and practical to be implemented for the users. Together with leadership in energy and environmental design (LEED) [26], they are the most widespread schemes.

Within this study, three main goals are to be met; (a) the monitoring of indoor air quality in cases of office buildings, (b) the evaluation of environmental aspects through qualitative analysis and (c) the linkage of the occupants' perception of comfort to environmental parameters. This approach enables both the quantitative and qualitative evaluation of the indoor environment, specifying the parameters that the policy makers need to consider so that the appropriate strategies and plans can be applied for achieving in the near future net zero energy building (nZEB) status.

Finally, during the qualitative evaluation, except for the traditional indices of thermal comfort, as set by Fanger, probable relation between the occupants' perception of comfort and a variety of environmental characteristics are studied [27]. In this line of approach, an integrated evaluation of the office buildings is presented, considering both the buildings' energy and structural capabilities, along with the occupants' needs and well-being.

Environmental evaluation

In order to determine a more personalized comfort approach in case of office buildings, an integrated methodological framework has been developed leading to the determination of the integrated personalizes comfort model of office buildings (IPCMOB) index [28]. As stated by Antoniadou and Papadopoulos [28], the structure of this index, has three main components; the building characteristics, the environmental conditions and the occupants' attitude. Regarding the indoor environmental aspect except for the indoor and outdoor thermophysical parameters that are taken into consideration, a variety of direct and indirect measured environmental aspects are considered.

Main target considering thermal comfort is to promote occupants' productivity, comfort, and well-being by providing living quality connected to thermal sensation and energy efficiency. In this line of approach, a variety of international rating systems have been established considering those aspects in their evaluation process. The determination of those parameters can help the designers and policy makers create more comfortable and environmental friendly buildings, achieving even the vision of green buildings. However, the determination of those aspects is not always easy, as a variety of psychological and individual parameters need to be considered.

Regarding the environmental aspect, LEED assesses the overall performance of buildings using environmental aspects such as energy efficiency, water consumption, indoor air quality, pollution, transport and sustainable sites selection, awarding credits for each environmental criterion according to the building's performance [29]. Moreover, as it is clear from those assessment criteria, a variety of environmental parameters have to be taken into consideration during certification as they influence the occupants' well-being and health [25, 26]. Also, the comfort parameter is evaluated. In detail, provide individual thermal comfort controls for at least 50% of individual occupant spaces is a criteria to be implemented when a building is certified by LEED. Furthermore, provide group thermal comfort controls for all shared multioccupant spaces, and for any individual occupant spaces without individual controls is evaluated. Thermal comfort controls allow occupants, whether in individual spaces or shared multioccupant spaces, to adjust at least one of the following in their local environment: air temperature, radiant temperature, air speed, and humidity. Moreover, a lot of emphasis is given to new materials used for new constructed buildings relating the issues of thermal comfort and energy efficiency with buildings' sustainable construction.

In case of BREEAM certification, fourteen parameters are considered for the evaluation of the environmental aspect. Those parameters are concentrating on the indoor environment conditions (air quality, lighting, acoustics, ventilation and comfort), office space, and windows' view; parameters that establish preferable work environment conditions [18]. Additionally, in the framework of a firmed environmental evaluation, aspects as neatness and waste management are of high priority with recycling, composting and reuse of material being the most popular and green applied methodologies. Furthermore, an evaluation of thermal comfort is indicated in the BREEAM rating system, with one point thermal modelling (or an analytical measurement/evaluation of the thermal comfort levels of the building) carried out using the predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD) indices in accordance with ISO 7730:2005 taking full account of seasonal variations. Local thermal comfort criteria have been used to determine the level of thermal comfort in the building, in particular internal winter and summer temperature ranges will be in line with the recommended comfort criteria within ISO 7730:2005, with no areas falling within the levels defined as representing local dissatisfaction.

Therefore, the determination of the relation between the environmental aspects and occupants' comfort constitute an important aspect of the analysis. In order to achieve an in depth evaluation, both the indoor air quality and the occupants' perception are to be considered.

In this line of approach direct and indirect measured parameters are evaluated. Regarding the direct measured parameters, thermophysical parameters along with direct evaluation the occupants' is preferred, whereas for the indirect parameters, a different approach is implemented. In the second case, a questionnaire survey is conducted where the determination of environmental criteria, as specified through BREEAM and LEED rating systems, evaluated by the occupants.

In detail, for the determination of the direct measured aspects, in situ measurements were carried out for both winter and summer period. During the measurement period special equipment was implemented and its placement along with its special characteristics were in compliance with the specifications of ISO 7726 [30].

Regarding the qualitative analysis, a revealed preference survey was carried out, specifying the occupants' perception of indoor environment conditions during winter and summer period. The implementation of this methodological approach is exceptionally popular and widely applied for the specification of indirect conditions and goods [31]. The applied methodology is divided in four different stages; (a) evaluation of criteria, (b) construction of questionnaires, (c) data collection and (d) data analysis.

Main goal of the analysis is the deduction of the environmental parameters and their influence on the occupants' comfort sensation during winter and summer period, leading to a sustainable indoor environment. In detail, the respondents were asked to evaluate the indoor environmental conditions and to express through a Likert scale their opinion concerning seven indirect measured environmental parameters that as outlined from green building certifications, BREEAM and LEED, affect the occupants' well-being. Those parameters are; (a) how productive the occupants feel during their stay in their offices, (b) in which scale does the indoor environment conditions contribute to their concentration level, (c) whether they are satisfied with their work environment conditions (decoration), (d) neatness and (e) window view of their offices, (f) the frequency of recycling and finally (g) their satisfaction concerning indoor air quality.

An implementation of the methodological approach is conducted in the framework of this study. Main outcome of this analysis is the determination of preliminary results indicating possible correlations between the occupants' comfort sensation and the environmental parameters, enabling both designer and policy makers to upgrade the existing buildings stock.

Case study

The aforementioned methodological approach has already been applied in three buildings evaluating the occupants' thermal comfort satisfaction and individual aspects. Main outcome of this initial implementation was that very promising results were attained regarding the relation between the occupants' comfort perception and a variety of individual characteristics [28]. However, an important component of the determination of the IPCMOB index is the environmental aspect.

Therefore, in addition to the implementation presented by Antoniadou and Papadopoulos [28], an implementation regarding the correlation among direct and indirect environmental aspects and the occupants' comfort is conducted on the same buildings through this study. The collected sample size is 106 questionnaires with an error of 4% and a confidential interval of 95% based on the population.

The under evaluation buildings, fig. 1, are two floor office buildings located in in Thessaloniki, Greece. The climate characteristics of the area based on the latest World maps of Koppen-Geiger Climate classification in 2017 are similar to a variety of coastal cities in the Mediterranean region [32-34]. All under evaluation building cases have openings in every

(a) (b) (c)

Figure 1. The under evaluation commercial buildings; (a) building A, (b) building B and (c) building C

façade and central heating and cooling systems. Also, they are all constructed in compliance with the thermal insulation regulation and their operation schedule is from 7.00 a. m. to 4.00 p. m.

More information for every case is also presented in tab. 1. Moreover, the case study is implemented in office buildings.

Table 1. Characteristics of the under evaluation buildings [35]

Building characteristics	Building A	Building B	Building C
Construction year	1998	1995	2002
Conditioned floor area [m^2]	518	844	4564
Openings	Double glazed, aluminum framed windows	Tinted, double glazed, aluminum framed windows	Double glazed, aluminum framed windows
Insulation	The roof, ground floor and bearing structure are externally insulated and the brickwork in the cavity		
Heating system	Central gas boiler that feeds radiators	Central geothermal system with heat pumps and fan-coils as terminal units	Central gas boiler that feeds radiators
Cooling system	Local heat pumps (room air-conditioners)		Central natural gas chiller
Ventilation	Natural	Natural	Natural and mechanical
Shadowing	Internal	No.	Internal and external

Results

In-situ monitoring

To achieve an integrated evaluation of indoor air conditions, the levels of CO_2, as a reliable representative index for indoor air quality are determined. The poor air quality in a building can lead to a variety of health problems on occupants and to a productivity decrease regarding their work [36]. Therefore, the monitoring of indoor CO_2 level is essential and can improve the indoor environment conditions and well-being of occupants in a building. To conduct this analysis, scientific laboratory equipment has been used. In detail, the CO_2 concentration sensor of Testo 480, with range from 0-10,000 ppm and accuracy at ±75 ppm has been implemented [37].

The results of the measurement period are presented in fig. 2 for the under evaluation buildings. Based on ASHRAE 62.1:2013, the indoor CO_2 levels are evaluated based on the outdoor CO_2 conditions. Therefore, accepted levels of CO_2 concentration of indoor environment are recommended from 1000-1200 ppm. However, extremely dangerous can be characterized conditions where the levels of CO_2 exceed 5000 ppm [36].

Regarding Building A, an office area of four permanent occupants and an important number of visiting citizens, has been monitored. The measurements during winter noted that the CO_2 concentration levels varying from 400-1200ppm, reaching even 1600 ppm. Those concentration levels can be considered as pleasant, as only temporarily they reached and exceed the maximum recommended by ASHRAE 62.1:2013. A similar CO_2 concentration pattern is monitored in case of Building B, fig. 2. Those outcomes are a result of the lack of an established central mechanical ventilation system and the differentiation of the population density in the under evaluation area. Moreover, the lack of a centralized mechanical ventilation system can be observed from the monitoring of the summer period. In this case, the CO_2 concentration levels are decreased as occupants tend to ventilate their offices for a longer period and also due to the reduction of occupants' density as a result of the vacation leaves of the employees and the reduced visits by the public.

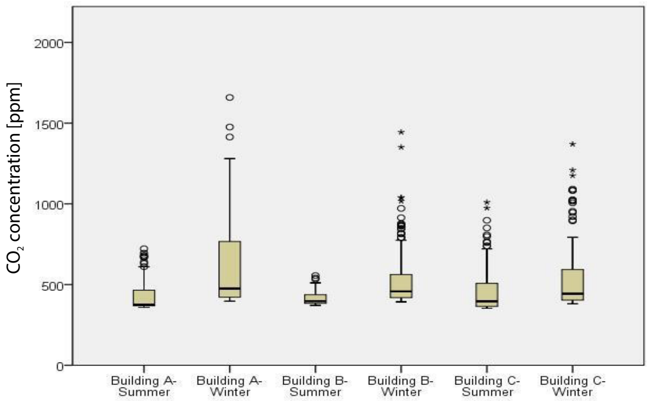

Figure 2. The CO_2 concentration levels of under evaluation areas during winter and summer monitoring

Finally, the analysis of Building C outlined that the CO_2 concentration levels, in both seasons, vary from 400-1200 ppm. In the area under evaluation, two people are working permanently whilst on a typical day fifty visitors enter on average the office area. The slight differences monitored between the two seasons are mainly a result of the constant ventilation of the area by means of the mechanical ventilation system.

Questionnaire survey

In addition to the in situ monitoring, a mathematical analysis based on a questionnaire survey is conducted. In detail, the implemented statistical analysis is divided in two main approaches, where a descriptive and an inferential statistical analysis are conducted. The latter is focusing on the correlations among comfort sensation and environmental parameters. The occupants of each building evaluated the aforementioned environmental aspects in a Likert scale from 1 (least satisfactory) to 7 (most satisfactory).

The final sample of the analysis, is composed of both male and female occupants with 43.4% of the respondents being men and 56.6% women. The age range of the respondents' specified is typical for office buildings as it varies from 26-73 years old occupants with a mean 45 years and a standard deviation of 8.239.

The evaluation of the indoor environmental conditions for winter and summer period, focused on the occupants' perception concerning air temperature, indoor air quality, lighting, noise and comfort conditions. In detail, in case of Building A, the indoor air quality is evaluated and the analysis denoted that 57.9% and 66.6% of the respondents describe it as moderate for winter and summer period, respectively. Moreover, the analysis stated that the majority of the respondents feel productive in their offices (72.7%) and characterize their satisfaction regarding their concentration levels as moderate (63.6%). Furthermore, the indoor environment conditions and especially the decoration of the area along with the neatness are evaluated. In both cases, most of the respondents by 63.6% and 68.2% are moderate satisfied with the indoor decoration and the neatness of the area, respectively. Also, the parameters of the window view and the frequency of recycling are analyzed and it is outlined that the majority of the respondents (59.1%) are not satisfied with their window view and they recycle every day (72.7%).

In case of Building B, the analysis documented that 76.2% and 57.1% of the respondents are moderately satisfied with the indoor air quality during winter and summer, respectively. Furthermore, high productivity and concentration levels are denoted from the majority by 85.7% and 66.6%. Other parameters under evaluation are the occupants' satisfaction regarding the indoor decoration, the neatness and the window view. Regarding the indoor decoration of the area, the majority of the respondents are moderately satisfied, whereas 28.6% are neutral and 42.8% moderately to satisfied, regarding the neatness, while 61.8% are highly satisfied with their window view. Moreover, the frequency of recycling is investigated and as specified, 52.4% of the respondents recycle every day.

In addition, the analysis in Building C showed that majority of the respondents are satisfied with the indoor air quality during winter and summer period, by 60.7% and 51%, respectively. Moreover, concerning the rest under evaluation parameters of productivity and concentration levels along with the satisfaction regarding decoration, neatness and window view, in this case, the majority of the occupants are satisfied. Another parameter that is considered is the frequency of recycling where the analysis stated that 55.7% of the respondents recycle every day.

Except for the descriptive analysis, an inferential analysis is carried out, determining probable correlations among perceived comfort sensation during winter and summer period and a variety of environmental parameters. The respondents were asked to determine their perceived level of comfort for both winter and summer in a Likert scale from 1 (unsatisfactory) to 7 (satisfactory) and their satisfaction regarding the under evaluation environmental aspects in the same Likert scale. Due to the nature of the data, a nonparametric Wilcoxon analysis is conducted and the results of the analysis are depicted in tab. 2.

Table 2. Correlations among occupants' comfort perception and environmental parameters

Correlations	Total comfort sensation during winter		Total comfort sensation during summer	
	Z	Asymp. Sig. (2 tailed)	Z	Asymp. Sig. (2 tailed)
Satisfaction of indoor air quality	–3.485	0.000	–2.475	0.013
Felt of productivity in the office	–2.063	0.039	–3.082	0.002
Concentration in the office	–2.272	0.023	–1.129	0.259
Point of view for work environment (decoration)	–3.923	0.00	–2.990	0.003
Point of view for neatness	–2.454	0.014	–1.255	0.209
Window view	–2.872	0.004	–2.084	0.037
Frequency of recycle	–4.859	0.000	–4.033	0.000

As deduced from the analysis the correlations presented in tab. 2 are statistically important correlated with a confidence interval of 99% (sig. < 0.05) but for the occupants' concertation and point of view about neatness in correlation to the total comfort sensation during summer. In detail, the analysis depicts a positive correlation among the occupants' perception of comfort during winter and summer period and the environmental parameters. Moreover, for both periods a positive correlation is documented between the occupants' satisfaction for indoor air quality and the comfort perception, figs. 3(a) and 3(b).

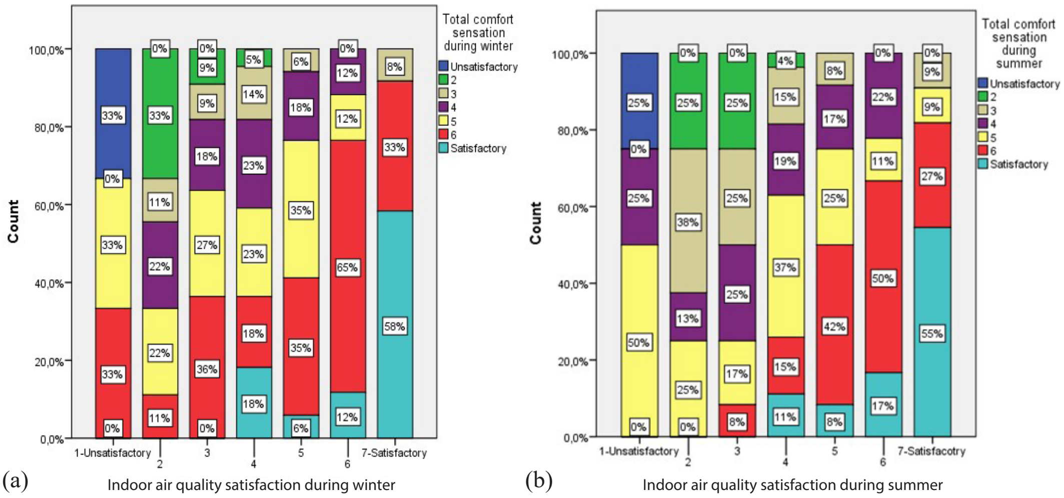

Figure 3. Relation between the IAQ and the total comfort sensation during; (a) winter and (b) summer

Furthermore, the analysis depicted that, the higher evaluation the occupants' credit their productivity, the higher their comfort perception is for both under evaluation seasons, figs. 4(a) and 4(b). Moreover, the more concentrated the occupants consider themselves in their office area, the higher their comfort sensation during winter is. Another environmental parameter under evaluation is the work environment conditions. In this case the majority of the respondents as presented in figs. 5(a) and 5(b) are satisfied with their work environment conditions (plants, pictures *etc.*) and as deduced from the analysis the more satisfied the occupants are with the indoor decoration and office environment, the higher the level of comfort sensation in both seasons is.

Moreover, the neatness of the area is evaluated and the analysis outlined that the more satisfied the occupants are with the neatness of their office area, the higher their comfort sensation during winter is. Regarding the occupants' satisfaction concerning their window view, the analysis outlined that the more satisfied the occupants are with the existing view, the higher their comfort sensation during winter and summer period is. The final correlation under evaluation is the one between the frequency of recycling and the comfort sensation. In this case, the correlation among the variables is once more positive with increase of the comfort sensation when the recycling frequency is high.

Therefore, it is safe to say that as expected and depicted from the literature research those environmental parameters are strongly and positively correlated with the occupants' comfort sensation, but for two parameters during summer.

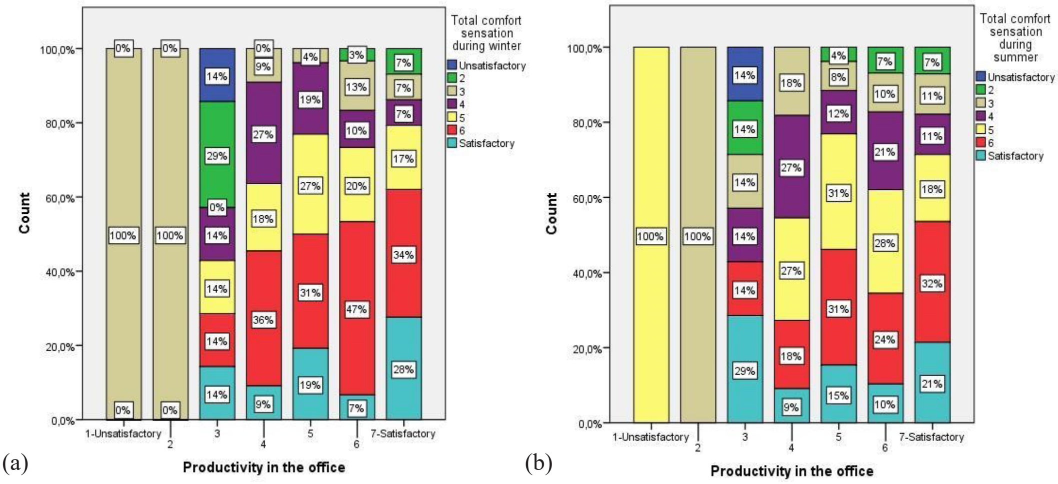

Figure 4. Relation between the occupants' productivity and the total comfort sensation during; (a) winter and (b) summer

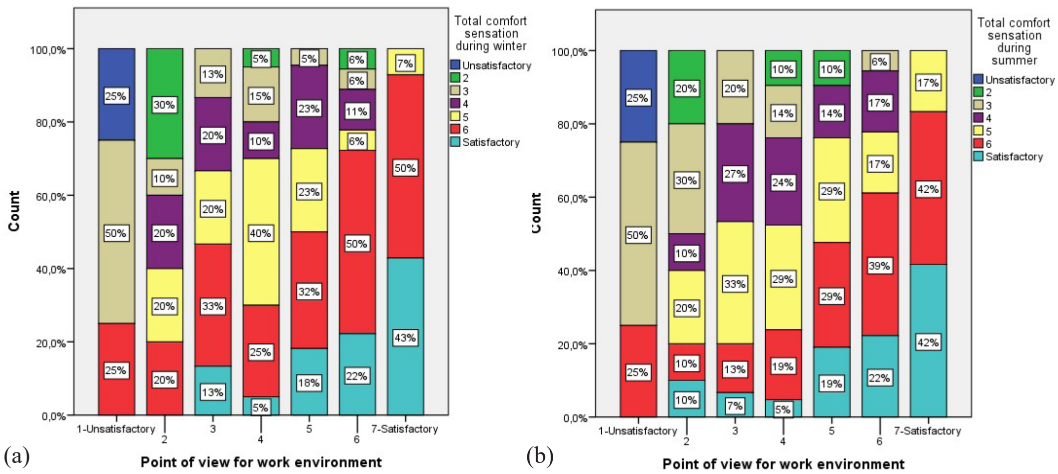

Figure 5. Relation between the point of view for the work environment and the total comfort sensation during; (a) winter and (b) summer

Conclusions

Environmental sustainability is essential and constitutes a main goal of the existing legislation, whilst it is expected to become even more important in forthcoming legislation considering the energy upgrade of the existing and new buildings. In this line of approach, an integrated methodological approach have been established by Antoniadou and Papadopoulos [28] where the existing indoor and outdoor conditions along with the environmental aspects are considered. In this line of approach, preliminary results regarding the environmental aspect are demonstrated in this study. In detail, an in depth determination and evaluation of the indoor environmental parameters is considered, along with the parameters that affect the occupants' perception of comfort sensation in office buildings, creating environmental friendly buildings with low energy footprint.

Regarding the results of the study, an in-situ monitoring was carried out, along with a revealed preference survey, leading to an in depth evaluation of the indoor environment conditions by means of directly and indirectly measured environmental parameters. The in situ monitoring denoted adequate indoor air quality conditions during summer and moderate during winter, in cases where ventilation is occurred by natural means. This outcome was also verified through the mathematical analysis by the occupants during the qualitative evaluation. Moreover, the results from the initial descriptive analysis are in compliance with the in situ monitoring as in cases of Buildings A and B the occupants' satisfaction regarding the environmental aspects is moderate and only in certain indirect measured parameters high. Main cause of this outcome is the lack of a centralized mechanical ventilation system. However, in case of Building C and in every under evaluation environmental parameter, a high satisfaction by the occupants' is specified.

In addition, an inferential statistical analysis was conducted, determining the existence and nature of probable correlations among the occupants' comfort sensation and a variety of environmental parameters. The analysis depicted that all parameters under evaluation are positively correlated with the occupants' comfort sensation during winter. In case of summer period, all under evaluation parameters but the concentration and neatness in the office area are specified as statistically important correlated. The deduced correlations also during summer are positive with the upgrade of any environmental parameter leading to an upgrade of the occupants' comfort sensation.

In conclusion, the analysis highlighted the need to determine and evaluate the existing correlations between the perceived comfort sensation and the environmental parameters that affect the occupants' well-being and productivity. Linking those parameters to the decision making stage of the design and construction process, is essential. Moreover, the adaptation and creation of a healthy and comfortable work environment that fosters the occupants' productivity and well-being is imperative, as they can help the policy makers accomplish the vision of a green building, not only concerning energy consumption but also the occupants, as the preliminary results of this study indicate. The study also showed, that further and more extensive analysis is needed, in order to document the interrelations between personal and thermophysical parameters.

Acknowledgment

The authors would like to express their gratitude to the Mayor of Pylaia-Hortiatis Municipality, and to the employees of the Technical Service, the former Town Hall and the Town Hall, for their support and their participation in the survey.

The survey and the study are carried out within the framework of the research project *Identification and Evaluation of the perceived level of comfort in office buildings using hybrid, personalized models*. The project was funded under the *RESEARCH PROJECT FOR EXCELLENCE IKY/SIEMENS*; the authors want to express their gratitude to IKY/State Scholarships Foundation for this.

References

[1] Papadopoulos, A. M., Aravantinos, D. Sanierung von öffentlichen bürogebäuden: ein bauphysikalisches problem, mit energiewirtschaftlicher Lösung. *Bauphysik*, *19* (1997), 6, pp. 177-185
[2] ***, Eurostat. (n. d.). Energy Consumption, Retrieved October 28, 2016, from http://ec.europa.eu/eurostat
[3] Papadopoulos, A. M., Forty Years of Regulations on the Thermal Performance of the Building Envelope in Europe, Achievements, Perspectives and Challenges, *Energy and Buildings*, *127* (2016), Sept., pp. 942-952

[4] ***, CEN (European Committee for Standardization), DS/EN 1525, Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics, *Geneva: International Standard Organization*, *54* (2007),
[5] ***, European Commision. Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the Energy Performance of Buildings, *Official Journal of the European Union*, (2002), pp. 65-71
[6] ***, European Commision. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings (Recast), *Official Journal of the European Union*, (2010), pp. 3-35
[7] ***, CEN (European Committee for Standardization). ISO 7730, Ergonomics of the Thermal Environment Analytical Determination and Interpretation of Thermal Comfort Using Calculation of the PMV and PPD Indices and Local Thermal Comfort Criteria, *Geneva: International Standard Organization*, *3* (2005), pp. 605-615
[8] Economidou, M., *et al*., *Europe's Buildings Under the Microscope: A Country-by-Country Review of the Energy Performance of Buildings*, Buildings Performance Institute Europe (BPIE), Bruxelles, Belgium, 2011
[9] ***, Greek Law 4122, Energy Efficiency in Buildings – In Accordance to Directive 2010/31/EC of the European Parliament and the Council, *Official Journal of Greek Government*, *42* (2013), A, pp. 639-654
[10] ***, Technical Chamber of Greece, Analytical National Parameter Specification for the Calculation of Buildings Energy Effi-Ciency and Publication of Energy Efficiency Certification TOTEE 20701-1/2010, *Technical Chamber of Greece*, (2010)
[11] ***, Hellenic Statistical Authority, National Population Census of 2011. 2011, Retrieved April 18, 2017, from http://www.statistics.gr/
[12] Theodoridou, I., *et al.*, A Typological Classification of the Greek Residential Building Stock, *Energy and Buildings*, *43* (2011), 10, pp. 2779-2787
[13] Karava, P., *et al*., Experimental Study of the Thermal Performance of a Large Institutional Building with Mixed-Mode Cooling and Hybrid Ventilation, *Building and Environment*, *57* (2012), Nov., pp. 313-326
[14] Akimoto, T., *et al*., Thermal Comfort and Productivity – Evaluation of Workplace Environment in a Task Conditioned Office, *Building and Environment*, *45* (2010), 1, pp. 45-50
[15] Choi, J. H., *et al.*, Post-Occupancy Evaluation of Twenty Office Buildings as Basis for Future IEQ Standards and Guidelines, *Energy and Buildings*, *46* (2012), Mar., pp. 167-175
[16] Liu, J., *et al*., An Investigation of Thermal Comfort Adaptation Behaviour in Office Buildings in the UK, *Indoor and Built Environment*, *23* (2013), 5, pp. 675-691
[17] Taleghani, M., *et al.*, A Review Into Thermal Comfort in Buildings, *Renewable and Sustainable Energy Reviews*, *26* (2013), Oct., pp. 201-215
[18] Cheng, Y., *et al*., Thermal Comfort Models: A Review and Numerical Investigation, *Building and Environment*, *47* (2012), 1, pp. 13-22
[19] Rupp, R. F., *et al*., A Review of Human Thermal Comfort in the Built Environment, *Energy and Buildings*, *105* (2015), Oct., pp. 178-205
[20] Yang, L., *et al*., Thermal Comfort and Building Energy Consumption Implications – A Review, *Applied Energy*, *115* (2014), 1, pp. 64-173
[21] De Dear, R. J., *et al*., Progress in Thermal Comfort Research Over the Last Twenty Years, *Indoor Air*, *23* (2013), 6, pp. 442-461
[22] Gossauer, E., Wagner, A., Post-Occupancy Evaluation and Thermal Comfort, State of the Art and New Approaches, *Advances in Building Energy Research*, *1* (2007), 1, pp. 151-175
[23] Frontczak, M., Wargocki, P., Literature Survey on How Different Factors Influence Human Comfort in Indoor Environments, *Building and Environment*, *46* (2011), 4, pp. 922-937
[24] Antoniadou, P., Papadopoulos, A. M., Occupants' Thermal Comfort: State of the Art and the Prospects of Personalized Assessment in Office Buildings, *Energy and Buildings*, *153* (2017), C, pp. 136-149
[25] ***, BRE. (n. d.). BREEAM. Retrieved January 15, 2017, from http://www.breeam.com/
[26] ***, U. S. Green Building Certification, (n. d.), LEED, Retrieved January 15, 2017, from http://www.usgbc.org/leed
[27] Fanger, P. O., *Thermal comfort. Analysis and applications in environmental engineering*, Thermal Comfort, Analysis and Applications in Environmental Engineering, 1970
[28] Antoniadou, P., Papadopoulos, A. M., Development of an Integrated, Personalized Comfort Methodology for Office Buildings, *Energies*, *10* (2017), 8, pp. 1202

[29] Giama, E., Papadopoulos, A. M., Sustainable Building Management, An Overview of Certification Schemes and Standards, *Advances in Building Energy Research*, *6* (2012), 2, pp. 242-258
[30] ***, CEN (European Committee for Standardization). ISO 7726, Ergonomics of the Thermal Environment – Instruments for Measuring Physical Quantities, 2002
[31] Samuelson, P. A., A Note on the Pure Theory of Consumer's Behaviour, *Economica*, *5* (1938), 17, pp. 61-71
[32] Kottek, M., et al., World Map of the Koppen-Geiger Climate Classification Updated, *Meteorologische Zeitschrift*, *15* (2006), 3, pp. 259-263
[33] Rubel, F., *et al*., The Climate of the European Alps: Shift of Very High Resolution Koppen-Geiger Climate Zones 1800-2100, *Meteorologische Zeitschrift*, *26* (2017), 2, pp. 115-125
[34] ***, World Maps of Koppen-Geiger Climate Classification, World Maps of Koppen-Geiger Climate Classification Update, 2017, Retrieved March 27, 2017, from http://koeppen-geiger.vuwien.ac.at/present.htm
[35] Antoniadou Panagiota, Papadopoulos Agis., Development of an Integrated, Personalized Comfort Methodology for Office Buildings, *Energies*, *10* (2017), 8, pp. 1202
[36] ***, ASHRAE Standard 62.1. *Ventilation for Acceptable Indoor Air Quality*, American Society of Heating, Refrigerating and Air Conditioning Engineers, 2013
[37] ***, Testo, *IAQ probe Manual*, 2015

Paper submitted: September 21, 2017
Paper revised: October 30, 2017
Paper accepted: November 21, 2017