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Advances in Applied Science Research, 2011, 2 (5):48-63

ISSN: 0976-8610
CODEN (USA): AASRFC

An analysis of user behaviour and indoor climate in an office building in Kosovo

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ABSTRACT

This work presents the results of a study on user behaviour and building systems in an office building in Kosovo. The main objective of the project was to observe and analyze indoor climate conditions as well as occupant's behaviour at workspaces, and to find measures to enhance the building's thermal performance and efficiency. In the study of the thermal performance of the office building, indoor data loggers were used to monitor events and states in seven offices over a period of six months (from December 2008 to June 2009). Events and states such as occupancy, temperature, relative humidity, illuminance and status of electrical fixtures were recorded every 15 minutes. The recorded data were processed and analysed. Based on the results from the research, the interaction between occupants and building systems was found to affect thermal comfort and energy use of buildings. Therefore, it is necessary to have accurate information about user control behaviour in office buildings in order to improve building performance and energy consumption. These behavioural patterns can be used to develop a basis for evaluating the influence of occupancy on building energy consumptions, building simulation programs and intelligent system control strategies.

Keywords: thermal comfort, user control actions, behavioural models, efficient systems.

INTRODUCTION

With most of the urban population spending many hours in office buildings [1], it is imperative to provide a good indoor climate and efficient building systems. The use of intelligent occupancy systems, daylight responsive lighting devices and controls have been found to save about 70% of electrical energy used in office buildings [2 and 3].

Another factor related to the high energy use of office buildings is the provision of thermal comfort. Thermal comfort is defined as the state of the mind which expresses satisfaction with the surrounding environment [4]. Thermal comfort however requires a subjective evaluation [5].

The factors affecting thermal comfort depend on four environmental and two personal parameters. The environmental parameters are dry bulb temperature, mean radiant temperature, relative humidity and air velocity whereas the personal parameters are clothing-insulation and physical activity. The evaluation of satisfaction at workspaces makes use of the above parameters to calculate the Predicted Mean Vote (PMV) and the Predicted Percentage of Dissatisfied (PPD).

Studies on user behaviour and interaction with building systems for comfort reasons have increased the knowledge and understanding of building performance. For instance, researchers [6 and 7] observed that the switching on or off of lights either happened when building occupants arrived or left their workspaces. Electrical lights are known to generally use 20 to 30% of a building's total energy. Besides, behavioural patterns have resulted in the effective prediction of energy performance of office buildings. These buildings are generally responsible for a considerable share of the total energy use and the major part of the use takes place after the production.

The study of user behaviour regarding switching actions in office buildings was first conducted by [7]. The conclusion was that all luminaries in one room were usually switched on or off at the same time. Other researchers found a close relationship between illuminance in the working area on arrival and switching the lights on by the occupants [8 and 9], (Fig 1)

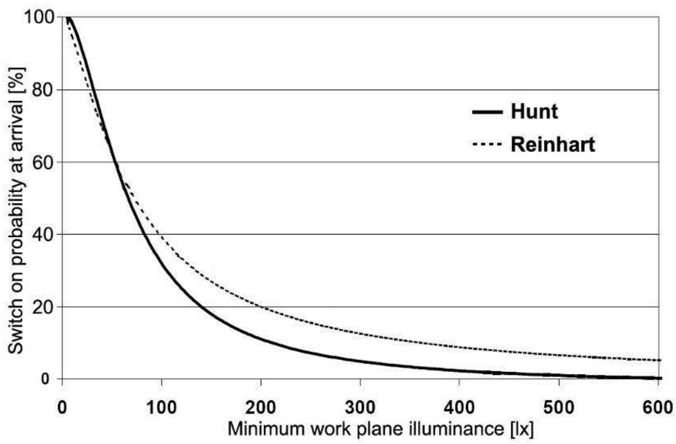

Fig 1 The probability of switching the lights on upon arrival by office occupants (Hunt and Reinhart)

Other researchers also monitored blinds and manual controls of electric lighting [10]. They tried to find out if manually controlled electrical lighting systems and automatically controlled blinds with manual impact were operated in relation or independent to each other. The study showed that there was an increasing probability of lights being switched on if illuminance was less than 100 lx [10].

Recommendations are given on the switching off of lights when offices are empty as a sustainable measure to save energy [11]. Further, efficient building performance is mainly related to the design of installed systems and the interaction with these systems by the occupants. Further, the conclusion that there are four main factors which should be considered in efficient building performance is propagated [11]:

Building technology; Installation technology; Smart controls of installation; and Interaction between behavioural aspects and energy saving technology.

The prime aim of other studies [12] is to create new technical and socio-economic solutions to make energy efficiency easy for end-users in existing and new office buildings. However, efficiency alone would fall short of sustainable principles if the behaviour of occupants is neglected. Other researchers found out that in buildings with efficient installed systems, negative behaviour of the occupants contributed to high energy use [1].

Notwithstanding the complex nature of thermal comfort, researchers are undertaking projects to better understand the production of heat and the associated responses by human beings, conscious feelings about the environment, and the processes of heat transfer between man and his surroundings [13]. Furthermore, they [13] found out that building occupants interact with available building systems in order to create pleasant indoor conditions.

In addition, studies conducted in air-conditioned buildings show that the occupants are not satisfied with the indoor climate during the winter and summer months. Even in buildings with sophisticated thermal controls, dissatisfaction with the indoor climate prevailed. Occupants tend to report on issues relating to overheating and under-cooling during the winter and summer months.

Against the background of high energy use of air-conditioned buildings as compared to naturally ventilated types, studies into user behaviour, installed systems and interaction with thermal control devices are paramount. In this context, the presented research deals with the study of user behaviour and installed systems towards the improvement of building performance and thermal comfort of office buildings in Prishtina, Kosovo.

MATERIALS AND METHODS

The main focus of the study is the OSCE (The Organisation for Security and Co-operation in Europe) building which is a representative of present high-rise and curtain walled facilities in Prishtina, Kosova. Henceforth, the case study building will be referred to as “HQ”.

The HQ building (see Fig 2) is curtain walled (reflected glazing) with a total of sixteen floors.

Fig 2 View of the HQ building at Prishtina, Kosovo

The seven observed offices are on the first, second, mezzanine, seventh and eighth floors with different orientations.

The offices and occupants

Seven offices of different sizes and orientations were monitored during the observation period (December 2008 to June 2009). For instance, the single occupancy offices were about 16m², triple occupancy 16m² and other multiple occupancy offices ranged between 30 to about 45m². The mezzanine is an open office landscape with 10 workers. The monitored office spaces are located on the first, second, seventh, eighth and on the mezzanine floors of the HQ building. Typically, the workspaces are carpeted whereas the corridors are of granite stones. The walls are painted in white and the ceilings are suspended. Fig 3 shows sample plans and orientations of the offices.

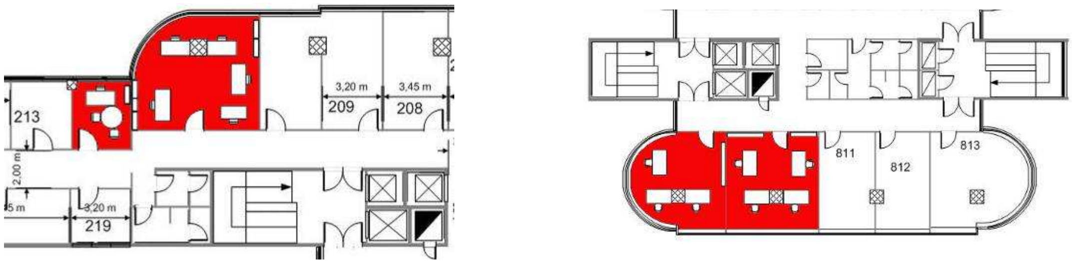

Fig 3 View of floor plan of multiple occupancy office on the second (left image) and on the eight (right image) floor

Building systems

The installed lighting systems are fluorescent tubes (18 and 36 watts) with two manually controlled switches located near the entrance. The centrally controlled heaters (radiators) are located under the windows. Due to the inefficiency of the central heating and cooling system, window air-conditioners have been installed in the offices to support comfort at the workspaces. The central heating, ventilation and air-conditioning (HVAC) systems are operated from 07:00 to 18:30. The cooling system is used from May to September whereas heating is provided from October to April. Also, there are internal shades which are manually controlled.

Data collection

From December 2008 to June 2009, data was collected to effectively study the thermal conditions and user behaviour in the offices. This was made possible through the use of sensors to monitor the indoor environment and occupant's operational activities. The data was recorded every 15 minutes and downloaded every 30 days using Greenline software. The software was also used to launch the sensors.

Indoor climate parameters (temperature, light intensity and relative humidity, presence of users and state of artificial lighting) were measured using two different types of data loggers (Hobo U12-012 and IT-200). The data loggers were mounted under the light fixtures and around the workspaces. When mounting the data loggers, direct sunlight was avoided and occupants were instructed not to deposit any items on the sensors. The sensors were named using a 12 digit code comprising the room number, sensor ID and installation date. For example, "103_201_081224" meant: room number 103, sensor ID 201 and installed on the. Fig 4 shows a sensor mounted at a workspace.

Fig 4 Sensor mounted at a workspace on the second floor

To monitor the presence of office workers at their stations, IT-200 loggers were used to log occupancy and the state of artificial lighting (on/off). The sensor (IT-200) utilizes passive infrared technology to detect and record occupancy and lighting status. Luminance is observed through a plastic pipe to determine if lights are on or off [14]. The loggers were installed in the immediate proximity of the luminaries and protected against direct sunlight. Also, the loggers were mounted in such a way that a clear view of the workspaces could be maintained. Every 30 days, the recorded data was downloaded using a laptop computer with ITProSoft (IT-200) software. The sensors were also named using a 12 digit code which comprised the room number, sensor ID and installation date. The sensor ID for IT-200 loggers starts with "1", for instance "103_101_081224" means: room number 103, sensor ID 101 and installed on the 24th of December 2008.

At the end of the observation period, the building occupants were interviewed on their views and perception towards their indoor climate. In all, 18 people responded to the interviews which were held through a set of questions. The questionnaire was structured in sections, with various parts dealing with personal and general information (gender, age, etc) of the occupants, issues related to indoor climate, the operation and accessibility of the occupants to the installed systems and system controls, etc.

Data processing

Over a period of six months (24th December 2009 to 30th June 2009), calibrated data loggers were installed in the offices to record indoor temperature, relative humidity, illuminance, occupancy, and light switching (on/off) states in seven offices. The extensive data collected was structured in MS Excel sheets and analysed. The processed data was further used to analyze thermal comfort [15] conditions in the offices. Thus, temperature, relative humidity values and metabolic rates were computed to calculate the predicted mean vote and the predicted percentage of dissatisfied. Also, psychrometric charts were generated to study the indoor thermal conditions in the building.

To efficiently analyse the data, SenSelect application was used to structure and synchronize the recorded values in 15 minutes time intervals. This application was based on Mathlab [16]. Further, a Notepad ++ application was used to convert the structured data from SenSelect and saved as CSV files. For the CSV files, MS Excel was finally used to import the data for a detailed analysis.

RESULTS

The results of the study are presented in sections. They are split into occupancy, lighting, thermal comfort and interviews.

Occupancy

Fig 5 illustrates the mean occupancy level and standard deviation over the course of a reference day for all monitored workstations (six in total). The diagram reflects the presence of the occupants at their workspaces and does not take into consideration when occupants are somewhere else within the building.

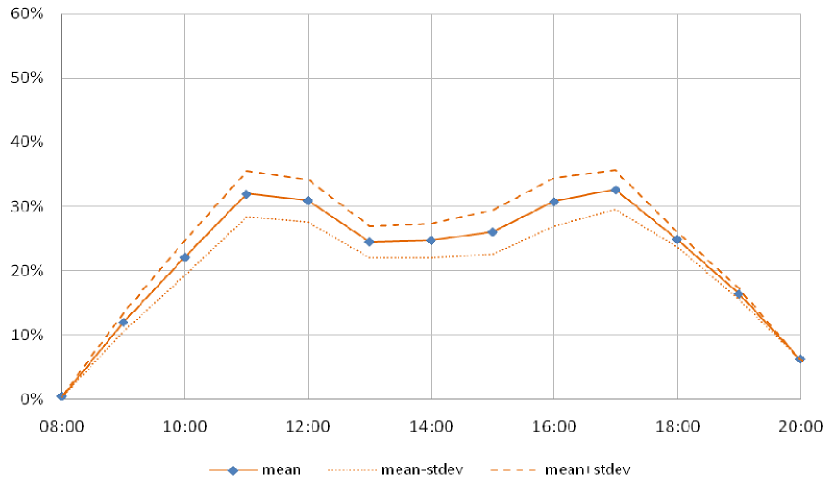

Fig 5 Mean occupancy level (%) over the course of a reference day (8-20hrs, averaged over all workstations observed)

Lighting

Similar to [7], the probability of switching the lights on upon arrival in relation to the working plane illuminance has been explored. Fig 6 demonstrates the probability of an occupant switching the lights on upon arrival in his/her office as a function of the prevailing task illuminance level immediately before the arrival. The illuminance range has been divided into bins of 100 lx. For each bin category, the total number of "switching on" events upon arrival has been divided by the total number of events "entering the office" ("switch on" + "remain off" events), expressed in percentage. Thus, the results for each bin ("switch on" probability) have been calculated in percentages with "n" being the "switch on" actions.

The calculated total number of switch-on actions (n=153) is very low as compared to the observation period of 6 months. This could be related to the occupancy results obtained (30 to 35%) within the study period.

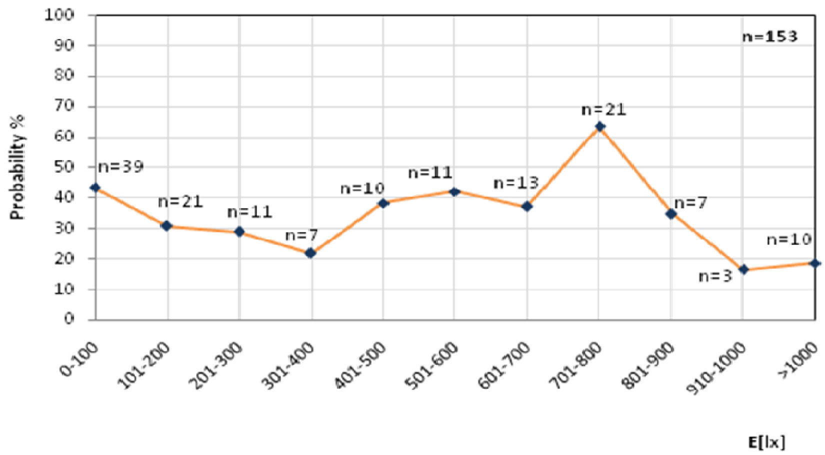

Fig. 6: Probability of switching the lights on upon arrival in the office as a function of the prevailing task illuminance level

Fig 7 shows the probability of the occupants intermediary switching the lights on (15 minutes before and after the switch action) and as a function of the prevailing task illuminance level. In all, 41 switch-on actions could be observed.

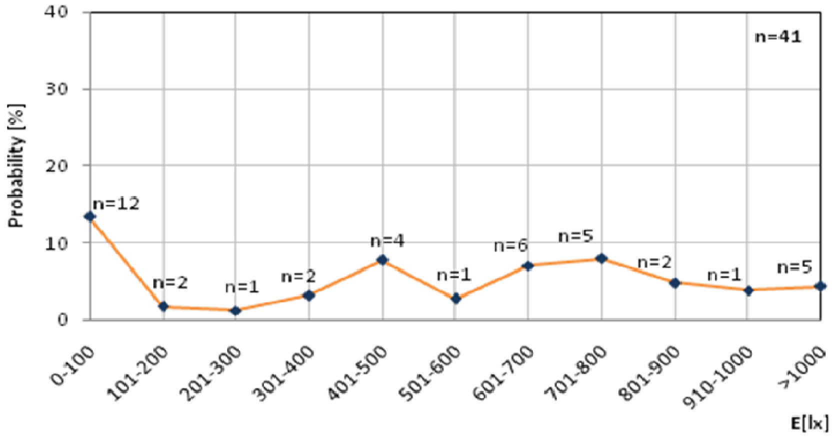

Fig 7 Probability of intermediary switching the lights-on in the offices as a function of the prevailing task illuminance level

Fig 8 shows the probabilities of switch-on actions upon arrival and before leaving the offices. In all, there are 243 switch-on actions by the occupants (15 minutes before and after the switch actions) upon arrival and before leaving the offices.

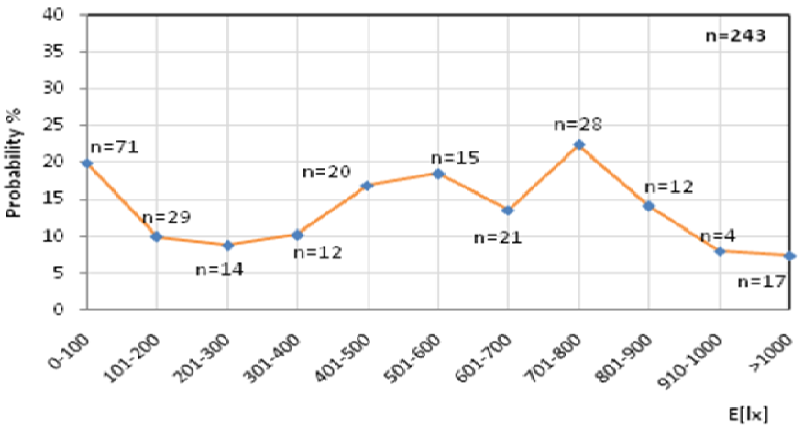

Fig 8 Probability of intermediary switching the lights on upon arrival in the offices as a function of the prevailing task illuminance level

Thermal comfort

To calculate the thermal sensation in the office spaces, the predicted mean vote (PMV) and the predicted percentage of dissatisfied (PPD) approach was used. Here, a scale of <-2 to >+2 was applied. The implication of the values are: -3 cold, -2 cool,-1 slightly cool, 0 neutral, 1 slightly warm, 2 warm, and 3 hot. Other values used for the approach are: Metabolic rate = 1.2 met; Clothing = 1.0 clo (suits, dresses typical for business people) and Air velocity = 0.15 m/s.

The following illustrations (Fig 9 and Table 1) show the results of the approach. Fig 9 shows the calculated PMV during the months of December, January, February and March as well as April, May and June. The diagram shows that the months from April to June are rather warm as compared to the other months. Consequently, the majority of the offices could be said to be performing well since the PMV values are mostly between the -1, 0 and +1 bin.

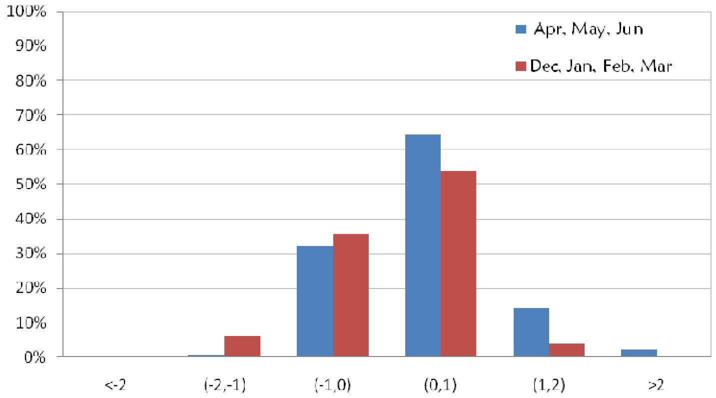

Fig 9 Mean distribution of calculated PPD (%) and PMV in all the offices

Table 1 shows the monthly predicted percentage of dissatisfied for each observed office. The office numbers 6, 7, and 8 show higher PPD values during the warmer months. PPD values in the offices 1, 1a, 3, and 4 are lower.

Table 1- Predicted Percentage of Dissatisfied – PPD [%]

Months	Offices and Orientation								Average
	1	1a	3	4	5	6	7	8	
	N-E	N-E	E	E	S	S-E	N-W	W	
December	11,8	12,8	20,1	18,5	40,1	9,4	14,7	18,1	18,2
January	11,9	11,4	11,5	10,8	18,8	12,0	12,0	12,9	12,7
February	8,7	7,3	8,3	7,4	15,6	27,9	14,2	11,3	12,6
March	9,8	8,1	8,8	9,0	12,1	15,4	16,1	12,9	11,5
April	8,2	8,2	8,2	8,2	12,8	20,2	26,2	21,8	14,2
May	12,8	12,8	12,8	12,8	16,7	40,1	38,4	21,9	21,0
June	7,2	7,1	7,2	7,2	19,4	42,9	41,4	29,7	20,3

Psychrometric charts

The tabulated mean hourly values (during the working hours, 8:00 to 17:00) of the measured data were plotted in psychrometric charts. First, the comfort zone for Kosova needed to be derived (in relation to the neutral temperature) and plotted on the psychrometric chart. Here, a method based on the aforementioned neutral temperature was applied [5]. The neutral temperature is known to be the temperature at which a person should neither feel too hot nor too cold. The range of comfort temperature for 90% acceptability is said to be 2.5°C below and above the neutral temperature, which depends on the mean monthly outdoor temperature (see Equation. 1).

$$Tn = 17.6 + 0.31 \times To.av \qquad \text{(Eq. 1)}$$

Tn is the neutral temperature
To.av is the mean monthly outdoor temperature

Further, the boundaries of the derived comfort zones (standard effective temperature boundary lines) give the implication that at higher humidity levels, temperature acceptance is reduced [5]. Eventually, the monthly comfort zones (December to June) was calculated and the measured temperature and relative humidity values were plotted on the charts. Fig.10 and Table 2 show that the number of working hour observations within the comfort zone is considerably low during the month of June. However, the month of April is comfortable (all points represented in the comfort zone). In the month of May, temperature values of less than 20°C were recorded. This was due to the use of installed environmental control systems, orientation of the workspaces and the low occupancy with associated low sensible heat output. Indoor environmental conditions during the winter months showed very low relative humidity values (ca. 20%) compared to comfort scale recommendations.

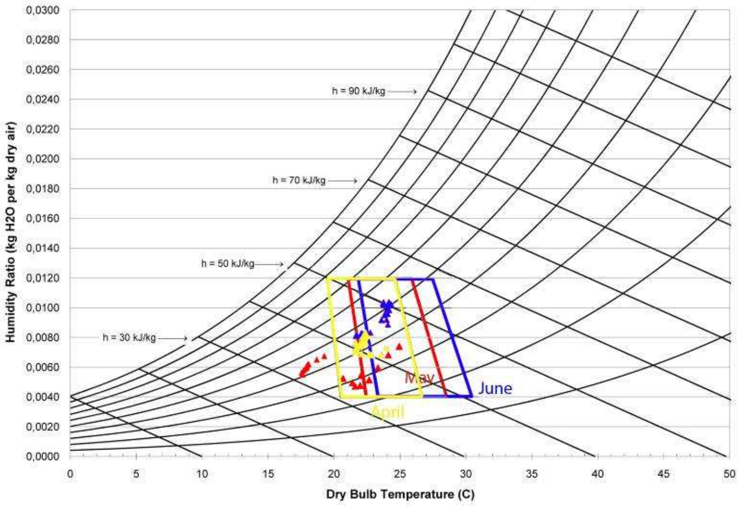

Fig 10 Hourly indoor temperature and relative humidity values in office nr.4 at the second floor during the months: April, May, June (8:00 – 17:00)

Table 2- Percentage of hours within the comfort zone [%] (warmer months of the year)

Months	1	1a	3	4	5	6	7	8	Average
April	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
May	64,8	64,8	63,0	65,0	64,2	65,9	49,8	65,1	62,8
June	48,0	48,0	51,0	51,0	46,9	48,3	48,3	44,0	48,2
Average	70,9	70,9	71,3	72,0	70,4	71,4	66,0	69,7	

Interviews

Fig 11 shows the percentage of occupants and their ranking of the perceived air quality. Most of the occupants had a positive view of the air quality.

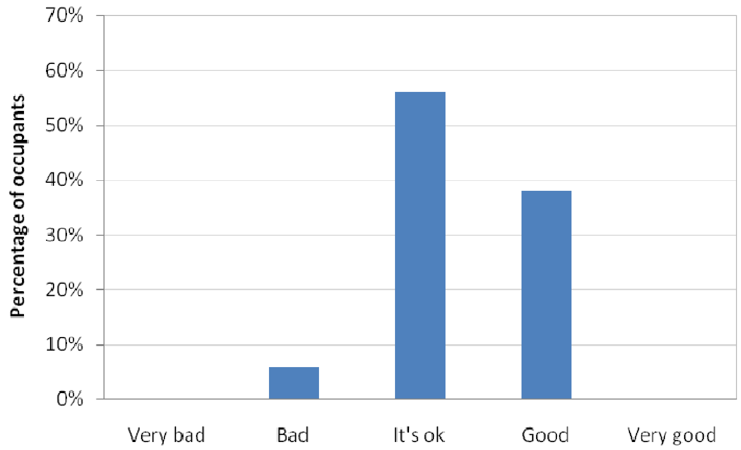

Fig 11 Assessment of air quality in the office

Fig 12 shows the percentage of occupants and their satisfaction with available ventilation possibilities. Furthermore, the vote on perception of temperature during the winter and summer seasons is illustrated in Fig 13, and Fig 14 shows the levels of satisfaction with the air-conditioning system.

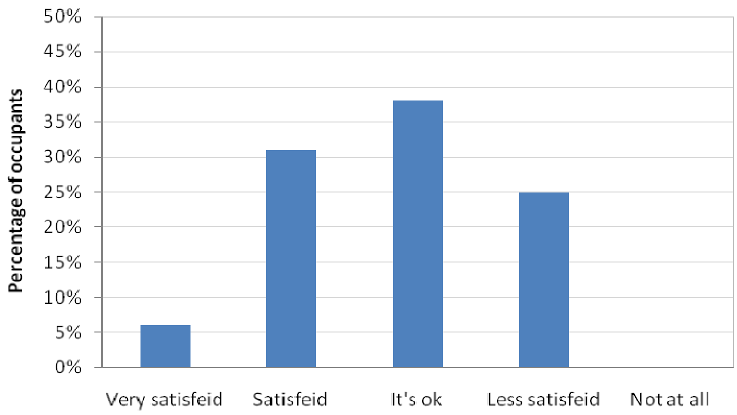

Fig 12 Satisfaction with the possibilities to ventilate the office

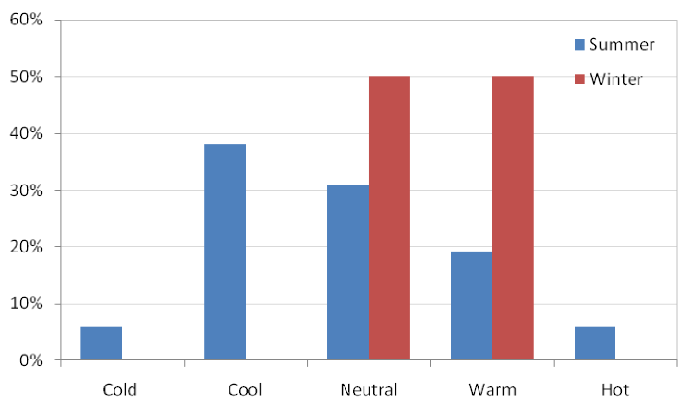

Fig 13 Assessment of the average temperature in the offices in winter and summer

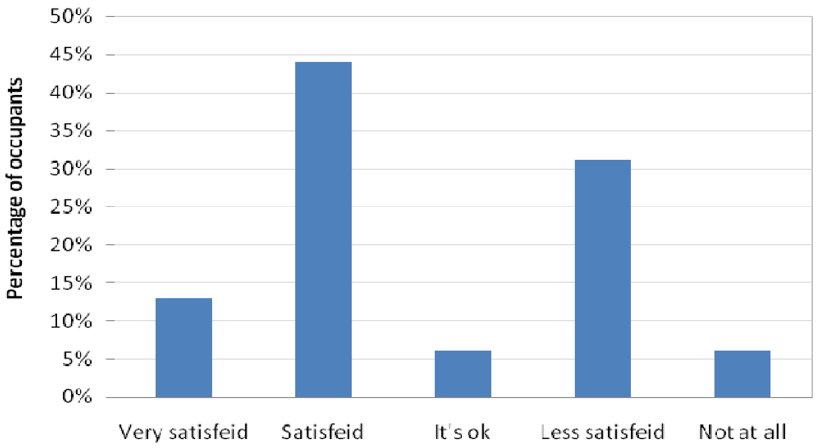

Fig 14 Satisfaction with the air-conditioning system in the offices

The percentage of occupants who were annoyed by direct sunlight and reflections on their computer screens are plotted in Fig 15. The plot also shows the frequency of annoyance in the offices.

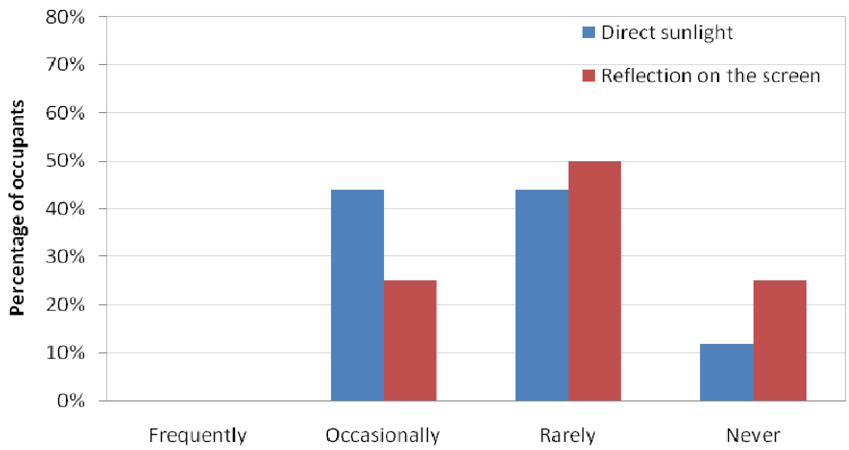

Fig 15 Occurrence of direct sunlight and reflection on the computer screen

Fig 16 shows occupants' assertion on the importance attached to the operation of windows. Most occupants were of the view that it is important to have the possibility to operate the windows.

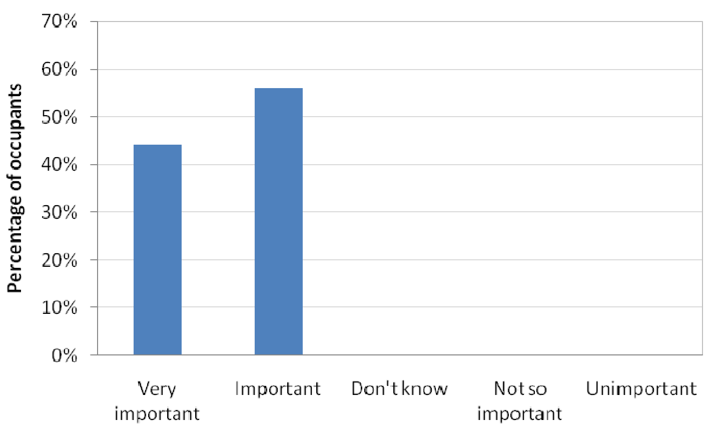

Fig 16 Importance attached to the possibility of operating the windows

A better air quality was seen as the most important measure needing attention. This gives an indication of dissatisfaction with the air quality by most of the interviewees (see Fig 17).

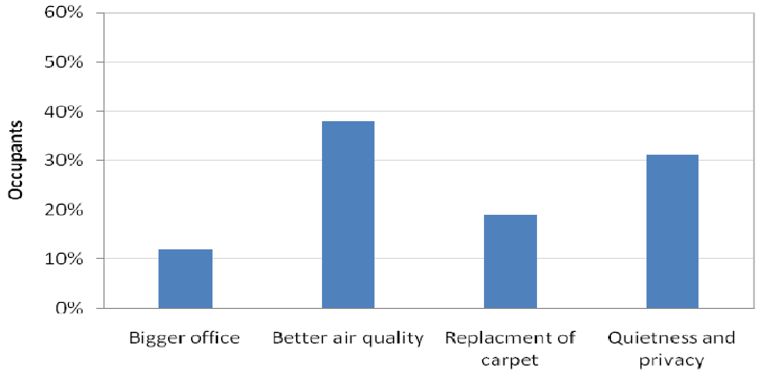

Fig 17 Votes on urgent improvement measures by the occupants

DISCUSSION

The results of the study are discussed and presented in sections. They are mainly the behavioural patterns of the occupants in interaction with the building systems, interviews resulting from the questionnaire and the thermal comfort analysis (PMV and PPD).

Behaviour

The occupancy pattern derived from the observation data shows that the offices were not fully used during the working time (8:00 to 17:00 hours). Fig 5 demonstrates that the mean occupied hours in the monitored workspaces was 30%. The low occupancy pattern in the OSCE (The Organization for Security and Co-operation in Europe) building could be linked to the background of the occupants (mostly international with limited contracts). Also, some of the occupants had field missions resulting in the low presence at the workspaces. The occupancy value of 30% is in contrast to the result of the study of office buildings in Vienna (mean occupancy of 60%, see [2]). Since the measurements at the observed offices showed occupancy of 30 % during the working time, it is not (economically) imperative that the thermal improvement of the building is the first measure to enhance its energy efficiency.

Artificial lighting

The behaviour of occupants with regards to the operation of artificial lighting is presented. The main concern was the frequency of switching-on lights. The observations regarding the operation of the light switches upon arrival showed that at an illuminance level of 100 lx, the occupants were more likely to switch on the lights (see Figs 6 and 7). However, at an illuminance level beyond 700 lx, the probability of occupants switching on the lights increased. An illuminance level of 700 lx would have been more than enough for desktop activities (recommended illuminance for office work is 500 lx). The behaviour of the occupants in relation to the use of artificial lighting could be said to be not energy conscious.

The reason for this negative behaviour could be related to direct and reflected solar radiation triggering the operation of shades. For instance, about 30% of the workers interviewed were of the opinion that there was too much daylight at their workspaces. Once the shades were deployed, the occupants resorted to the use of artificial lighting to increase illuminance at the workspaces. Furthermore, partly deployed shades resulted in poor contrast at the workspaces. This visual discomfort could have led the workers to switch on the lights. Generally, the absolute numbers of switching actions were low and this could be related to the low occupancy levels in the offices (30%) (Figs 7 and 8).

Interviews

The number of respondents to the interviews conducted was eighteen. The general information received showed that most of the occupants were between the ages of 25 and 35 years. Based on self assessment, most of the working time was spent in the offices. However, occupancy data retrieved at the observed workstations contradicts the above assertion.

On the perception of the interviewees on the prevailing air quality in the offices, most of the occupants were of the view that the quality was good (see Fig 11). But when asked about the most important measure needing improvement, 38% of the workers voted for the air quality (Fig 12). A detailed analysis of the data showed that high dissatisfaction was reported by those occupants who could not operate the windows (first floor windows were not operable). The rest of the floors had operable windows and the occupants were more satisfied with the possibility to ventilate the offices.

Fig 13 illustrates the satisfaction with temperature during the winter months. Most people interviewed had a positive notion of thermal comfort. About 50% had a positive view on comfort (cool/cold) during the summer months. Generally, the majority of workers were satisfied with the heating and air-conditioning system (see Fig 14).

Asked on the perception of lighting, about 31% of the workers voted for "too much/a bit too much" daylight and the majority were satisfied with artificial lighting. The outcome on issues in relation to daylight (reflections on computer screens) could be due to the orientation of the workspaces, the glazing quality and distance to the windows (Fig 15). In addition, a positive view (100% of the occupants) was expressed with the possibility to operate the windows (Fig 16). This result correlates to other studies on occupants in air-conditioned buildings (especially when windows are not operable).

Most of the workers who answered the set of questions were in multiple occupancy offices and about 50% were satisfied with independently operating the building systems (windows, shades, lights, etc) without negotiations. The majority of workers were of the opinion that the light switches were easily accessible.

Moreover, about 50% of the interviewees were not sufficiently informed, knew nothing about training programmes in the building and were disturbed about the operation of the ventilation system. This was more evident on the first floor where the windows were not operable.

On questions related to energy conscious behaviour in the operation of building systems, about 38% said that they were aware that control actions could influence energy consumption and about 50% considered energy use when operating the installed systems. The assertion of influence on building energy use through the operation of installed systems relates to the results of studies done in office buildings in Ghana and Austria [see 17, 18, 19 and 20] respectively. Unfortunately, most occupants in the OSCE building were not well informed on behavioural factors to save energy. These could be linked to the age and educational levels of the occupants since the two factors are known to affect environmental awareness [21].

The most urgent measure needing attention in the offices was air quality (Fig 17). This was followed by quietness and privacy. This could be related to the predominantly multiple occupancy nature of the offices in the OSCE building.

About 25% wished for the carpet to be replaced (annoyance by dust). Other disturbances were on health issues (eyestrain or burning, backache, headache and general fatigue) which seem to be frequently reported in office buildings [22]. The issues on health complaints are mostly linked to poor air quality, pollution from building materials and visual discomfort through glare [23, 24, 25 and 26]. The measured relative humidity values were low and this could have lead to about 31% of the occupants having eyestrain or burning sensations. Respiratory problems and nasal irritations were less frequently reported.

Thermal comfort

To derive and analyse the thermal conditions prevailing in the offices, psychometric charts were used. Relative humidity in the offices was very low (17 to 18%). The reason could be linked to the inefficient central heating system (winter period). The occupants also used the installed air-conditioners to heat the workspaces during the winter months. The very low relative humidity values could be related to the 31% of the occupants who had frequent eyestrains as health complaint. In addition, the adaptive comfort theory on which the comfort zones are based suggests a minimum temperature of 21.5°C as comfortable. The poor performance of the offices during the winter months was a surprise. Nevertheless, the month of April was satisfactory while the month of May and June were remarkably comfortable (Fig 9). In Table 2, the percentage of working hours represented in the comfort zone is illustrated. Satisfactory values were tabulated for the month of April, May and less satisfactory values for the month of June (higher temperature values were recorded for the month of June).

Using the approach after [15], the Predicted Mean Vote (PMV) and the Predicted Percentage of Dissatisfied (PPD) were calculated. Considered assumptions were for normal office work (metabolic rate and clothing values). Generally, the results show that the monitored offices performed quite well. The offices at the mezzanine and second floors (offices 3 and 4) were thermally better than those at the first and upper floors.

Conditions recorded for the months of April, May and June showed higher PMV values, especially in the office numbers 6, 7 and 8. These offices also showed higher PPD values during the months of April, May and June (see Table 1). The reason for this result is – in the case of office 7 – most probably the fact that the office was unoccupied most of the time. The reason for this circumstance in offices 6 and 8 is less clear. Sporadic observations indicate however that the occupants of the latter offices operated (closed) their shades less frequently. This may have resulted in higher solar gains and thus higher PMV values.

The results of the interviews indicated that the occupants perceived (retrospectively) the winter months as warmer (see Fig 13). However, PMV results suggest a slight shift to higher values in the summer (see Fig 9). This discrepancy might be partially the result of the assumed versus actual clo-values of the occupants. In PMV calculations, a constant clo-value was assumed. In reality, the summer time clo – values could have been lower.

CONCLUSION

Over a period of 6 months, indoor environmental parameters and occupant's behaviour were monitored in the OSCE building in Prishtina, Kosovo. The empirical study had the aim of contributing to the understanding of user behaviour and thermal performance in office buildings.

The study showed that the workers in the building were not always at their workspaces (30% mean occupancy recorded). This was different from their assertion with regards to presence at workstations. One reason for the low occupancy was the short term employment contracts and field trips of some of the occupants.

With regards to the probability of switching on lights, only 153 actions were recorded during the study period. This was rather low and could be due to the nature of work of the occupants and the resulting low occupancy level.

The study also showed that the thermal conditions in the offices were not fully satisfactory. With the exception of April, all the winter months' plots on the psychrometric charts were outside the comfort zone. The relative humidity values recorded were very low (ca. 20%). This may have negatively affected the occupants, as indicated by the interview results.

In addition, the interview outcome revealed that the occupants were not well informed regarding available building systems and training possibilities. Moreover, 62% of the workers did not know whether they could influence building energy consumption through their actions whereas about 50% thought about energy saving aspects when operating the installed systems. Finally, 94% were of the view that the air quality was good but that the most urgent measure needing improvement was the air quality.

Based on the results of the study which also correlates with most of the outcome of the thermal performance (behavioural, comfort, satisfaction and energy issues) of office buildings in Ghana, the following is recommended:

- There is the urgent need for facility managers to inform and train occupants on building systems and their operation.
- The outcome of the occupancy pattern (30%) indicates a poor usage of the building's spatial resources (mostly observed in offices with field work).
- The very low relative humidity values during the winter months indicate that some humidification may be necessary (the month of January and February records low humidity values of 20 to 30% in southern Ghana (recommended minimum to be over 30%)).
- The actual building occupancy and use patterns deviate significantly from typical assumptions in simulation studies.
- The building's performance and its energy efficiency could benefit from an intelligent system control strategy (shades, lights, ventilation).

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