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BUILDING OCCUPANCY CERTIFICATION: DEVELOPMENT ON AN APPROACH TO ASSESS BUILDING OCCUPANCY

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Abstract

Improving energy efficiency in commercial buildings is of great importance, given the large percentage of energy consumed in the sector. However, the incentives to save energy in these environments are unusual. From the perspective of managers, energy consumption is only a very small part of the financial burden of companies in comparison to materials, rent or salaries, and thus, economic incentives have a low impact in these environments. On the one hand, unlike in home environments, occupants of office building do not see a direct financial effect on their energy related occupancy practices, as so, their incentive is also not a monetary one. Thus, to effectively reduce energy consumption in office buildings, a different approach should be followed. The Building Occupancy Certification System (BOCS) project aims at developing a building evaluation system focused on the building's occupancy instead of its technical or physical characteristics. The objective of BOCS is the reduction of energy consumption in office buildings while improving indoor conditions. In this regard, the improvement of indoor conditions and thus, productivity, is the incentive for company managers and staff to implement the BOCS system. Though, keeping environmental awareness visible in the agenda. This paper presents the preliminary results from the first BOCS pilot study in the Netherlands, regarding the building performance in terms of thermal comfort and indoor environmental quality. This study focuses on the data collection and analysis.

Keywords:

Building occupancy; office buildings; monitoring; thermal comfort

1 INTRODUCTION

Improving energy efficiency in commercial buildings is of great importance, given the large percentage of energy consumed in the sector. However, the incentives to save energy in these environments are unusual [1]. Often, companies do not own the building they occupy and therefore any investment on low carbon technologies is out of their hands. In addition, energy consumption is only a very small part of the financial burden of companies, in comparison to materials, rent or salaries, and thus, economic incentives have a low impact in these environments (Joosstens 2014, oral communication). On the one hand, unlike in home environments, occupants of office building do not see a direct financial effect on their energy related occupancy practices, as so, their incentive is also not a monetary one. In addition, occupancy behaviour is greatly affected by the type of building and its installations. Very environmentally friendly occupancy patterns in an energy inefficient building will not show up in the energy bill, and so, the efforts of the occupants would not be visible or rewarded. On the other hand, a very wasteful occupancy in a very energy efficient building might hinder the buildings' performance, but might not be discovered looking only at energy figures. Thus, to effectively reduce energy consumption in office buildings, a different approach should be followed.

The Building Occupancy Certification System (BOCS) project aims at developing a building evaluation system focused on the building's occupancy instead of its technical or physical characteristics. The objective of BOCS is the

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reduction of energy consumption in office buildings while improving indoor conditions. In this regard, the improvement of indoor conditions and thus, productivity, is the incentive for company managers and staff to implement the BOCS system. Though, keeping environmental awareness visible in the agenda.

The purpose of the BOCS system is twofold. Firstly, it will provide a more accurate building performance assessment, which will be useful to building owners and financial institutions to take decisions regarding the implementation of renovation schemes and low carbon technologies. Secondly, it will provide building managers and users with the necessary information to decrease the energy consumption and carbon emissions during the occupancy phase of the building.

The impact of BOCS is related to three main objectives: to increase the occupants' comfort and satisfaction with their environment; to decrease energy consumption in the building; and to change occupants behaviour toward more sustainable practices. All of the above are of course, deeply connected. To achieve these objectives, the BOCS system comprises three different activities: 1) monitoring indoor environment, contextual parameters and occupants' behaviour, 2) engaging occupants into providing self-report data regarding their comfort and activities [2,3], and 3) providing feedback to occupants (e.g. managers, staff, facilities managers) regarding occupancy practices and their (positive or negative) effect on energy consumption and indoor environment. This paper reports on the first BOCS pilot in the Netherlands, which focused on indoor environment and self-reported comfort.

2 DATA AND METHODS

The BOCS approach aims at researching office occupant social practices, as well as designing, developing and testing solutions for improving these practices, all of which are supported by a dedicated BOCS platform. The BOCS aims to employs state of the art monitoring and information systems to gather information about indoor parameters, occupant behaviour (occupancy practices); and indoor comfort [4]. All the measured data has a direct or indirect effect on energy consumption and indoor environmental quality. Therefore, the system is based on the quantitative assessment of occupancy practices and factors related to energy consumption and indoor environment.

Monitoring building performance is necessary to develop and establish the building occupancy evaluation system. The data collected during monitoring activities in the buildings will be included in the BOCS database, which will be the basis for the building certification system. The data will provide the information needed to define the efficiency of diverse building operating practices and behaviours.

In the first phase of the project, we identified indoor comfort as the most challenging data collection for the project. Therefore, the first BOCS pilot focused on self-reporting indoor comfort data. Energy consumption and building operation are thus, out of the scope of this paper. There are two methods to collect data for the evaluation of thermal comfort: measurements of indoor parameters, and application of thermal comfort surveys [5,6]. The first method involves physical monitoring of the building (thus, objective data) while the surveys gather subjective data from the occupants and expresses also preferences for thermal comfort and differences between individuals.

Data collection tools have been developed for the Building Occupancy Certification System (BOCS) The BOCS platform has been developed to facilitate development behavioural change solutions. The platform consists of monitoring of sensor and self-reporting nodes, optional feedback devices, online interfaces, and a back-end for collecting and processing gathered data. The resulting approach provides a way for organising research, innovation and implementation of solutions in a living lab context, which allows parallel execution of research and innovation, providing new opportunities for addressing the challenges of social practice change [4]. The approach is organised around the BOCS platform, which is a software and hardware platform supporting performing of objective and subjective measurements in context, providing feedback to users, while also allowing easy modifications and addition of features by employing a modular system architecture.

The BOCS platform has been designed to support the system's flexibility and ability of fast adaptations regarding types of collected data, types of sensors used, types of self-reporting interfaces, and to support rapid development of context-specific screen-based, as well as physical feedback interfaces. Using the platform, two data collection devices were developed: the BOCS Sensor Box and the Self-reporting device.

The Sensor Box has been developed using modular electronic components. The version of the Sensor Box used during the pilot reported in this paper consists on sensors measuring CO2 concentration, humidity, sound level, temperature, light intensity and movement were used. The integration of indoor parameters and contextual data within one single box was decided to test the complexities associated to the placement of the sensor boxes within the offices, and the number of boxes required per monitored

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building. The pilot version of the sensor box can be seen in Figure 1.

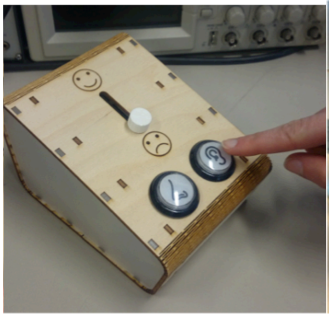

Fig. 1: Sensor box.

Fig. 2: Self-reporting device.

The self-reporting device was developed after the co-creation sessions with participants from the monitored office building [4]. The device aims at providing a vehicle for the participants to provide reliable input on their personal comfort. As result of the co-creation sessions, it was decided that participants should be asked their feedback on thermal comfort, air quality and noise level, since these were the factors that the co-creators (participants in the co-creation session) considered as important issues in their workspaces. However, the participants stressed their preference to only provide input when they were feeling discomfort. Although the researchers acknowledged the risk for the self-reporting device to become a 'complaining tool', it was decided to test this solution in the first pilot. The self-reporting device for this first pilot can be seen in Figure 1.

3 RESULTS FIRST DUTCH PILOT

This section shows the preliminary results of the summer pilot monitoring campaign in a large building complex in South Holland, The Netherlands. The main activity of the institute located in the monitored building is research and development of technology.

The purpose of the pilot was manifold. Firstly, the pilot aimed at testing the co-creation workshops in the working environment. These sessions are documented in a companion paper. Secondly, the pilot aimed at testing the Sensor Boxes and Self-reporting devices created after the co-creation workshop both in terms of reliability and usefulness of the information collected. Thirdly, the monitoring pilot campaign aimed at providing insights into the data analysis and communication of results of the building performance.

The Building Occupancy Certification System aims at providing insights into the building occupancy performance in three aspects: energy savings, indoor environmental quality, and occupancy practices. Within the indoor environmental quality, we find two different aspects of investigation: the objective measurements and evaluation of the indoor quality, and the subjective experiences from the occupants of the building.

For the first pilot study, the energy savings potential of the monitored buildings was not measured, since the very small sample size of the pilot (number of participants in the study in comparison to the number of occupants in the building) would not generate any kind of measurable impact on energy savings. In addition, in this phase of the development of BOCS, design interventions to change behaviour and thus to reduce energy consumption are not yet applied.

Two buildings were monitored during the summer pilot, both buildings have been built in the seventies, but the EF building has been renovated. A range on building characteristics was sought in order to test the different data collection methods and solutions, however, the inclusion of a building without natural ventilation was not possible given the lack of enough measuring devices. The main characteristics of the reported monitored building are in Table 1.

	Building EF
Orientation rooms	South-west
Heating system	Active chilled beams
Heating control	Local thermostat (+3, -3)
Cooling system	Active chilled beams
Cooling control	Local thermostat
Ventilation system	Mechanical air handling unit
Openable windows	Yes

Table 1: Main building characteristics of the monitored building.

3.1 Indoor environmental quality

Indoor environmental quality refers to thermal comfort and air quality. Several parameters can affect the thermal comfort in a building. For the purpose of the BOCS evaluation, we focus on three main aspects that can be monitored: indoor temperature (in Celsius), indoor air quality (in CO_2 ppm) and indoor relative humidity.

To evaluate the above-mentioned parameters, we make use of the ASHRAE international standards to determine the range of conditions (Temperature, RH, CO_2 level) in which the building is considered to be comfortable for the majority of occupants. These ranges are shown in Table 2.

The Percentage of People with Discomfort (PPD), based on the PMV or Predicted mean vote, is a model that calculates the percentage of people that will be uncomfortable in the building. However, the PMV only applies to buildings in which the occupants have no control on their environment (e.g. cannot open windows or change temperature settings). Therefore, we use the Adaptive model, in which the acceptable

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range of temperature is calculated based on the external temperature.

Following sections show the results of the building performance evaluation of one selected building based on temperature, Relative Humidity, CO2 level and the adaptive model. The results are presented per monitored room in the EF building.

Building category	Temperature summer (^{o}C)	Relative humidity (%)	CO2 above external level (ppm)
A	23.5-25.5	30-50	<350
B	23.0-26.0	25-60	35-500
C	22.0-27.0	20-70	500-800

Table 2: Indoor parameters ranges in the standards (ASHRAE 55-2007)[7].

3.1.1 Temperature

The ranges of temperature considered acceptable by international standards (ASHRAE) are shown in Table 2 for the summer and winter. The table show the ranges for each type of building category. The category is defined according to the age and characteristics of the building. The monitored building is in categories B (Renovated buildings). All the figures are shown in percentage of working hours in which the building is within the acceptable ranges.

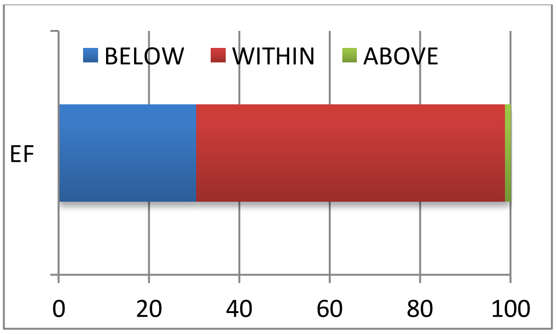

Fig. 2: Percentage of working hours outside accepted range in building.

Figure 2 shows that Building EF is more than 30% outside of the accepted ranges for temperature in the summer. The figure also show that the building is colder than what is considered acceptable. The offices in this building have local control for the air conditioning, implying that the users prefer lower than accepted temperatures.

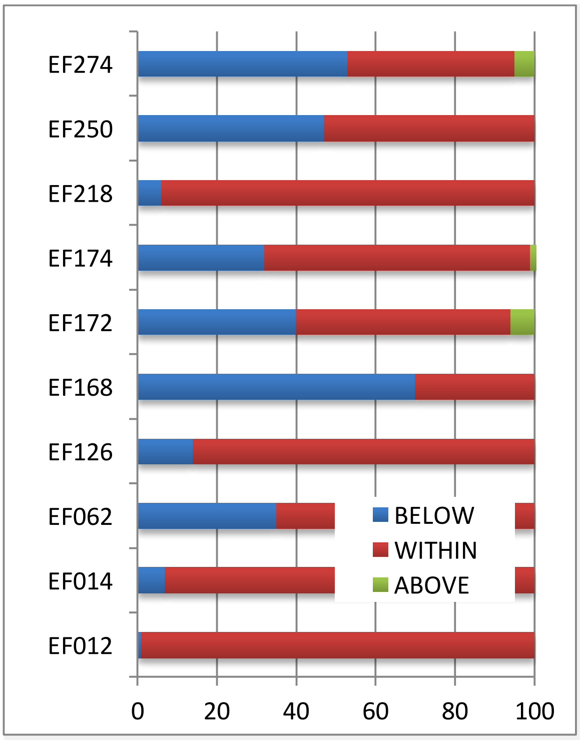

Fig. 3: Percentage of working hour outside accepted range per room.

Figure 3 shows that in some rooms, the temperature below the accepted range can reach up to 70% of the time. On the other side, according to the figures, rooms do not particularly suffer from overheating. Overheating temperatures only occur in three of the monitored offices and for less than 5% of the time. It is important to notice that the EF building has a south orientation, which in theory could cause overheating in the summer.

We can conclude that building EF might be cooled down more than necessary according to the acceptable ranges provided by the international standards. However, research has shown that the actual thermal comfort of buildings' occupants highly depends on the external temperatures. Thus, the following section investigates the performance of the buildings in relation to the adaptive model.

3.1.2 Adaptive model

The adaptive model temperature has been calculated per each hour of the monitored period, for which data from a weather station in Valkenburg, South Holland, has been used.

The figure shows the same trend as the results from the temperature ranges: summer indoor temperatures tend to be lower than required, and there is barely overheating during the monitoring period. However, Figure 4 shows that, considering category 2 (C2), the percentage of time that the temperature is lower than required, is small.

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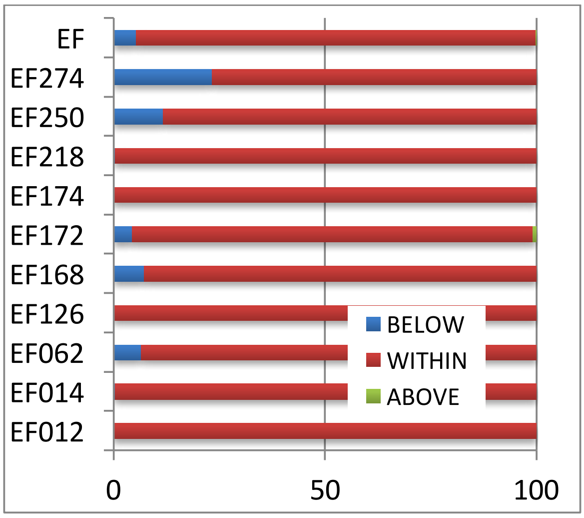

Fig. 4: Percentage of time within adaptive model comfort ranges.

3.1.3 Relative humidity

Relative humidity is evaluated based on building category B (healthy range is 25-60%). The relative humidity in all offices is within the accepted values on working hours, with exception of office EF168 where humidity was higher than recommended during working hours for 1.5% of the time.

3.1.4 CO2 level

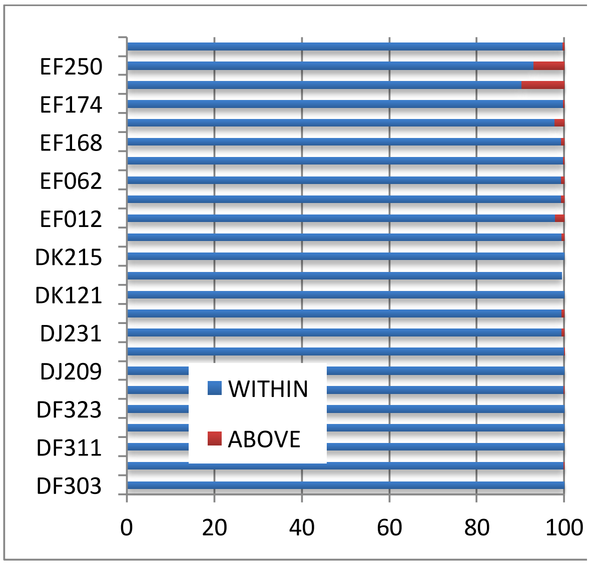

Fig. 5: Percentage of working hours within acceptable CO2 ranges.

Table 2 shows the accepted thresholds for indoor CO2 concentrations in each of the building categories. The results are shown in percentage or working hours within the accepted ranges. Figure 5 shows that the CO2 level is almost always within the accepted range (considering category B) in all offices during working hours. Therefore, we can conclude that the occupants ventilate enough to keep a healthy indoor air quality.

3.2 Self-reported (subjective) parameters

The occupants were asked to report on three different parameters: thermal comfort level on a 5 level scale and complains for noise and air quality. In the reported building EF, 18 participants in 8 different offices were recruited. To self-report on thermal comfort, the occupants were provided with a slider on the self-report device. For complains about noise and low air quality, the occupants were provided with a single button for each parameter. The self-reporting device is shown in Figure 2.

3.2.1 Self-reported (thermal) comfort

Figure 6 shows the average comfort per each of the participants. The mean represents the average thermal comfort votes reported by each participant. The figure shows that in building EF, all but one person tend to rank their comfort on a positive scale. However, it is not clear whether the occupants understood the icon on the self-reporting device as 'thermal comfort'.

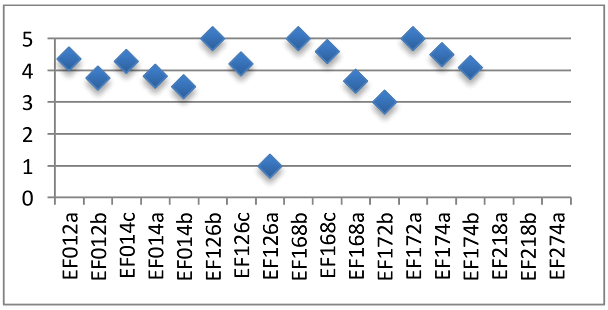

Fig. 6: Average thermal quality votes per participant in building EF.

3.2.2 Self-reported noise level and indoor air quality

Figure 7a shows the number of times each participant reported a complain about the noise level in their office. The maximum number of votes over a two week period was 24 votes. Figure 7b shows the number of times each participant reported a complain about the air quality level in their office. The maximum number of votes over a two week period was 26 votes. However, most participants voted less than 10 times. Both figures show that participants using the same room had very different number of complains about noise and air quality, which points at how subjective is this information.

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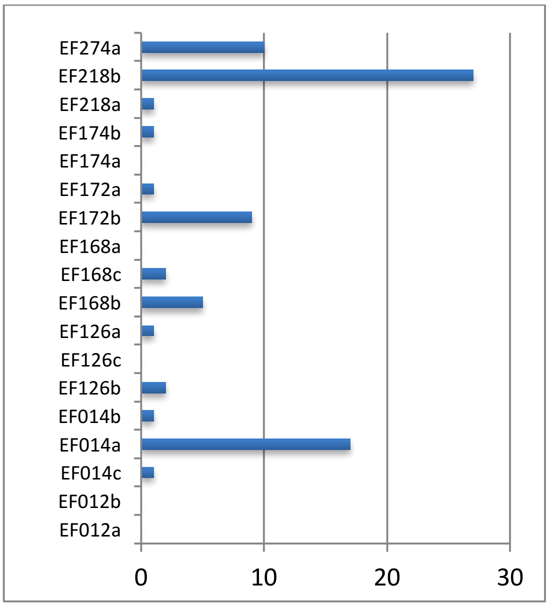

Fig. 7a: Number of complains for indoor air quality for all participants in all buildings.

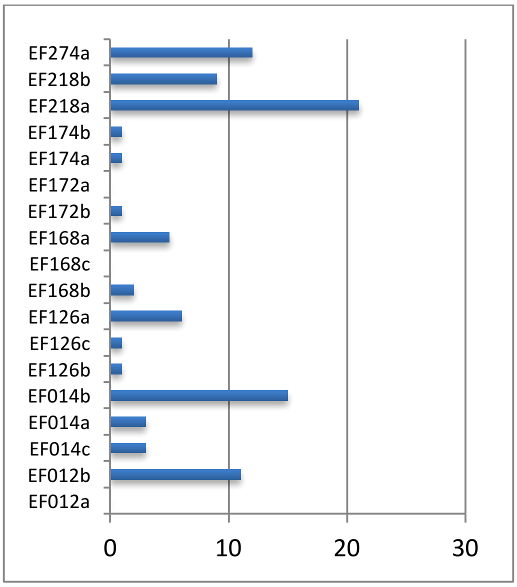

Fig. 7b: Number of complains for noise for all participants in all buildings.

4 DISCUSSION AND CONCLUSIONS

This paper reports on the first pilot of the Building Occupancy Certification System project (BOCS). The project aims at developing a platform to provide relevant building performance and management information to the occupants and managers of commercial buildings.

This pilot aimed at developing and testing devices to collect and analyse relevant data on indoor environmental quality and comfort. The devices had previously been co-designed with a selection of occupants of the monitored building.

The results showed that the objective data collected provided useful information on the indoor environmental performance of the building when coupled with local weather data. The use of the adaptive model seemed to be more suitable than using temperature ranges provided by ASHRAE, since the high comfort ratings of people indicated that the building was most of the time within comfortable ranges.

The analysis of the subjective data showed several shortcomings in relation to the usability and relevance of the data to evaluate building performance. Firstly, it was not clear whether the participants understood the slider in the Self-reporting device correctly as indicating thermal comfort, since only a happy or sad face was printed on the devices. Secondly, the use of the devices as a ‘complaining tool’ provided too little information for the analysis, and therefore, it was not possible to analyse the data statistically or in relation to the objective data.

Although the participants indicated, during the co-creation sessions, their desire to only use the self-reporting device when feeling discomfort, it is important to consider for further phases of the study, the limitations of an approach in which the user is given total liberty to design data collection tools. Further iterations of the project will be aimed at provided more reliable subjective data.

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