PLEA 2017 EDINBURGH
Design to Thrive

Users in context: actions and practices in low energy buildings

Gabriela Zapata-Lancaster[1] and Chris Tweed[1]

[1] Welsh School of Architecture, Cardiff University, Cardiff, United Kingdom, zapatag@cardiff.ac.uk

Abstract: One of the key challenges of the building industry is to achieve the expected performance in buildings in-use. The literature shows significant gaps between the as-designed and in-use building performance. There is a pervasive assumption among design practitioners and facilities managers that the occupants and their actions in buildings are a primary source of these 'performance gaps'. This paper contests two misleading notions that underlie that assumption: 1) the view that the user is a 'passive agent' in the built environment; and, 2) the view that there is a 'typical' user that can be applied universally. This paper presents a study that investigated the occupants' actions in four BREEAM certified buildings, comparing their as-designed and in-use performance. The study applied post occupancy evaluation techniques and user studies to investigate occupants' practices to provide explanatory detail to monitored environmental and energy consumption data. The paper focuses on occupants' actions and facilities management practices enacted in the everyday operation of buildings: what users do to achieve comfort, which include reconfiguration within spaces, adaptation through clothing, and operating building technologies; and, the facilities management strategies to operate the building. All of these take place against a background of institutional policies and norms. The observed actions and reported practices bring challenges to the typical representation of users and facilities management practices embedded in as-designed models of building performance. Therefore, an in-depth understanding of the context of building use considering different stakeholders' perspectives is deemed valuable to inform effective design strategies for building performance as well as to develop interventions to reduce the energy consumption of existing buildings.

Keywords: in-use building performance, building user, energy consumption, comfort, post occupancy evaluation

Introduction

The building industry is facing increasing demands to create energy efficiency buildings and reduce the carbon emissions of the building sector. The non-domestic building sector accounts for 20 per cent of carbon emissions in the UK. Therefore, attention is centred to improve the performance of existing non-domestic buildings. A review of the energy performance gap in the non-domestic sector suggests that 10-80% of the performance gap found in operation could be attributable to occupants' actions (van Dronkelaar et al., 2016). Typically, approaches to reduce energy consumption during operation have emphasised control strategies that restrict the actions of the users as a means to prevent their inconvenient and inefficient energy behaviour. However, building performance is the result of design features and their effectiveness to meet the expectations of occupants (Cole et al., 2010). Occupants' actions and any resulting performance gap could originate in how the occupants' expectations are met (or not) in the everyday use of buildings. There is a need to understand the actions and behaviours of everyday use and operation of buildings as a way to inform strategies for the efficient operation and management of existing buildings and for the building industry to learn from real buildings in operation and improve future building design (Janda, 2011, Fedoruk et al., 2015). The literature highlights that building occupants do not operate in a vacuum. The occupants have and exert agency to achieve desired conditions and to develop the actions in the daily occupation of buildings. In the context of non-domestic buildings, the individual and group agency of occupants could also be shaped by the social and cultural context (Lorch, 2008, Inalhan et al., 2010). Human agency manifests in the social context of use (Krippendorff, 2006). Krippendorff argues that the user should be regarded as 'knowledgeable agent whose actions are not arbitrary'(Krippendorff, 2006). Building upon the literature, this paper presents a research that investigated the users' actions and management practices relevant for thermal comfort in the light of the organisational culture and policies of four BREEAM certified buildings.

Methodology

The study applied post occupancy evaluation techniques and user surveys to identify occupants' satisfaction with and actions to modify indoor environmental conditions (thermal, lighting, acoustics) in four case studies. The purpose of the study was to identify how the social and organisational aspects encouraged (or discouraged) the occupants to modify the indoor environmental conditions and informed the management and the operation of the buildings. This paper focuses on the findings related to thermal aspects, referring, as relevant, to other indoor environmental conditions to highlight the nexus between thermal, lighting and acoustic conditions in providing the conditions for the satisfactory use of buildings as perceived by the research participants. The case studies were four BREEAM Excellent buildings: two schools and two offices buildings, certified to BREEAM 2006 version. Table 1 summarises the key performance aspects of the case studies.

Table 1. Summary of the case studies

Case Study	1	2	3	4
Building type	Office	Office	School	School
Location	South Wales	SW England	SE England	South Wales
BREEAM Rating	Exc.(73.89%)	Exc.(74.42%)	Exc.(71.97%)	Exc. (73.42%)
BREEAM version	Offices 2006	Offices 2006	Schools 2006	Schools 2006
Area m2	3736	1130	10996	2116
BER $KgCO_2/m^2$	24.88	14.81	11.40	8.50
%better2006 regs	40.85	12.90	33.91	37.9 0
BREEAM Energy	14 credits	10 credits	14 credits	15 credits
EPC desg.[in-use]	A [B(31)]	A	A [B(27)]	A [C(72)]
*Features for energy efficiency	NVB, Rad, Wind-man, Wat-boi	LZC, UFH, NVB, Wind-CO_2, Wind-Man, Wat-solar	>15% by LZC, UFH, NVB, Wind- CO_2, Wind-Man, Wat-solar	15% by LZC, UFH, NVB, Wind- CO_2, Wind-Man, Wat-solar

*Abbreviations: (LZC) Energy supplied by low zero carbon technology; (UFH) Underfloor heating, (Rad) radiators, (NVB) naturally ventilated building, (Wind-CO2) operation of windows by CO2 levels, (Wind-man) manually operated windows, (Wat-solar) solar thermal for water heating, (Wat-boi) Boiler for water heating

The indoor environmental conditions (temperature, CO_2 levels and relative humidity) and the electricity and gas consumption were monitored for a year. The user studies were carried out across four visits (one per season) and comprised semi-structured interviews, questionnaires and walkthroughs. The studies collected qualitative data about actions and perceived satisfaction with energy and indoor environmental conditions (thermal, lighting and acoustics). They included an additional spot monitoring exercise that recorded the indoor environment parameters (internal air temperature, mean radiant –globe-temperature, relative humidity, illuminance levels and ambient noise level) to link users' satisfaction and actions to the monitored conditions on the day of the visit.

User studies—Instruments

During the user studies (one visit per season), the environmental conditions were monitored at 10-minute intervals, recording the internal air temperature (°C), mean radiant (globe) temperature (°C), relative humidity (%), illuminance levels (lux) and ambient noise levels (dBEqA). A morning and an afternoon reading of external air temperature were recorded on the day of the visit. The equipment used for monitoring the conditions during the visits were: (1) Testo 435 anemometer to record the air speed and the temperature; (2) Digital impulse sound level meter Dave D14-22C and calibrator Serial # 3742070; and, (3) Eltek squirrer data logger 1000 server to record the globe temperature, lux and relative humidity.

User studies—qualitative study

The user studies investigated the occupants' actions and management practices in the buildings. Questionnaires were administered to students and employees in the case studies. The questionnaires included questions about the perceptions, satisfaction levels, knowledge of systems and controls, actions taken to achieve comfort. Three questionnaires were administered per seasonal visit: one general questionnaire and perceptions/actions in the day repeated in the morning and in the afternoon of the seasonal visit. The general questionnaire included questions about the building in general. The repeated questionnaires focused on reporting about the space where the respondent is based. The repeated questionnaires data were analysed in the light of the indoor environmental data monitored on the day. In addition to the questionnaires, semi-structured interviews with open-ended questions were conducted to facilities managers and different user representatives (teacher, employees in the office, head teacher and office manager). The mix of participants enabled to depict multiple perspectives with regards to how the buildings were used: the end-user engagement in everyday use of building (ie. data from employees), the medium-long term management of facilities (ie. data from facilities manager), the corporate norms and impact on the building management activities (ie. data from the head teacher, office manager). The length of the each interview was between 45 and 60 minutes. Documents such as the Operation and maintenance manual and the BREEAM reports were analysed to identify the as-designed energy and environmental performance intentions.

Findings

The users in all of the case studies expressed their willingness to take action to modify their immediate indoor environment to achieve comfort when the indoor conditions were not satisfactory. The main reason for dissatisfaction in the buildings was overheating, which was reported at different times of the year as shown in Table 2.

Table 2 Temperature recorded during seasonal visit (Tmp °C)and percentage of occupant's complaints due to overheating (Ovht %)

Seasons	CS 1	CS 1	CS 2	CS2	CS3	CS3	CS4	CS4
	Tmp °C	Ovht %	Tmp °C	Ovht %	Tmp °C	Ovht %	Tmp °C	Ovht %
Summer	24-25.6	71.43	23.2-24.4	85.71	24.5-28	66.70	27-31.8	100.0
Autumn	21.6-22.6	37.50	23.7-24.1	28.57	21.6-22.6	100.0	21.7-23.75	60.0
Winter	23-24.5	28.57	22-24		22.6-23.3	66.70	20-21	
Spring	24-25.4	14.29	22-24.5	14.29	24.8-25.5	60.00	19.8-21.5	77.78

The types of action taken by the research participants to improve their thermal comfort were: reconfiguration of spaces to match the location of workstations to individual thermal preferences (those who tend to feel hot next to windows, those who tend to be cold next to radiators); personal adaptation (i.e. adding/removing layers of clothes and taking hot/cold drinks); operation of windows and doors; use of fans and fan heaters.
Occupants in Case Study 1 (office building) were encouraged by the management team to exert adaptation strategies to achieve comfort: flexible dress code, relocation of workstations in the office and the use of personal fans and lamps in the workstations. The location of the workstations for individual employees is based on their thermal preferences. Employees working on the second floor, an open plan office area, chose the location of their desks (next to a window, in the core of the space, on the perimeter of the office by a radiator):

Interviewee CS1: 'We have had people who specifically asked to move desks to somewhere else because they were hot or cold. One of our girls used to sit near the window but she is really cold so when other of the staff wanted the window opened, she was not happy. But of course, the ones in the middle wanted to get a bit of flow of air so she moved away from the window and near the radiator so in the winter she would have the radiator. So people have said I don't like it here, it's too hot, too cold and moved appropriately to a better position.... still you can't please everybody but we've tried the best we can to sit people in a position that make them in a more comfortable environment.

A personal fan and fan heater are used in 75% of the individual workstations. The support provided at corporate level to the employees in Case Study 1 to be comfortable is motivated by the desire of the company to enhance the employee's productivity by increased comfort.

The research participants in all the case studies expressed their willingness to modify the thermal conditions of the spaces that they occupy. This was manifested by adaptation actions exerted at personal level and at building/technology level. The typical actions at building/technology level included the operation of windows and doors and the use of fans. However, some building features and control strategies in the case studies did not support adaptation despite the design intentions. For example in Case Study 4, the teachers expressed their desire to use windows and doors to improve the ventilation in the classrooms for thermal comfort and for fresh air. However, these actions were restricted by the layout of the school. The manually operable classroom windows in the first floor open to a buffer ventilation area. The ventilation area was originally designed for minimum occupancy, as a play area when the weather conditions did not allow the use of outdoor play area. The buffer area is a double-height space connected to the nursery area on the ground floor and adjacent to classrooms with manually operable windows on the first floor. The buffer area has been converted to a permanent play area for nursery children on the ground floor due to lack of spaces, restricting the use of the operable windows of the classroom in the first floor. When the windows in the classrooms are open, the noise from the nursery disturbs the classroom activities (78dBC). While the doors of the classrooms could be open for ventilation, the teachers prefer to keep the doors closed to avoid noise from the corridor (113.4dBC). When the building overheats, the teachers tend to switch off the lights in the classrooms to limit the lighting heat gain. This action in turn compromises the lighting levels in the classrooms (267-305lux). These classrooms also have windows at ceiling height that are automatically controlled on the basis of CO_2 levels. These windows open to the exterior but cannot be manually operated because they are out of reach (approximately 2.60m high). The caretaker in Case Study 4 reported that the CO_2 levels that trigger the operation of the windows are changed seasonally so that the automatic windows open more frequently in summer (to reduce overheating) than in winter (to prevent incoming cold air). The CO_2 levels that trigger the opening of windows in winter is 1250-1750ppm. In summer season, the CO_2 level trigger point is 750-1550ppm. This strategy, however, is problematic when the CO_2 levels rise and there is rain, cold air or drafts due to outdoor weather conditions and during autumn and spring. It should be noted that CO_2 levels can build up to unadvisable levels in winter; yet, the windows remain closed. Another criticism of the automatic windows was the noise and disruption created when they open during teaching activities that required concentration. In Case Study 4, the occupants wanted to modify the immediate environment (which in turn could increase their perceived satisfaction in the building); however, there were limited opportunities for the occupants to use effectively the building features (windows, doors) to support adaptation.

A similar situation was reported in Case Study 3. The research participants expressed their desire to exert a range of adaptation actions: personal (clothing according to the season) and to operate the building technologies in the spaces that they occupy (windows, doors, blinds). However, at organisational level, some school policies limited the adaptive opportunities available to occupants. In terms of personal actions, the dress code for employees strongly recommends suits and ties to be worn all year round to present a professional image to the students and parents. Occupants were not allowed to wear lighter clothing in summer. For the operation of building technologies, there was a policy to not operate windows or blinds in the spaces adjacent to the main façade. The intention was to maintain the uniformity of the main façade to avoid that this facade '*looks as if it is missing some teeth'* when some windows/blinds were open while others remained closed. The use of windows in upper level floors was also restricted due to safety concerns.

The facilities manager in Case Study 3 reinforced this view by expressing his discontent with the corporate expectations about his role. He felt that there was little support for him to promote activities to reduce the energy consumption. He thought that he was expected to focus on the provision of the physical conditions of classrooms (sufficient space, number of computers, chairs and resources for teaching) rather than the management of indoor environmental conditions and energy performance. He felt that the actions to manage the indoor environmental conditions were supported at corporate level if triggered by unexpected problems in the classrooms rather than as a planned programme of management and maintenance. It should be noted that this was the only case study with onsite availability to BMS data. However, there were problems with the metering and possible data corruption. Yet, there had been no support to fix the BMS problem which prevented the facilities manager from having robust recorded energy and environmental data that could inform medium and long-term plans for performance management.

The data indicate that the organisational policies shape the management practices and actions available to the occupants to achieve thermal comfort in the case studies. For example, in Case Study 2, the facilities management role was fulfilled by a team offsite. Case Study 2 is a building that belongs to an institution with its main headquarters in a different location. The Estates department deals with the energy management of the building, including the automated building controls and the access to the monitored data by the BMS. There is limited control directly available to the building occupants in Case Study 2 to modify their indoor environment. The windows operate automatically on the basis of CO2 (like Case Study 4) although the occupants can override the system and operate the windows manually. There is no dedicated facilities manager in this building. When a problem arises in Case Study 2, a technician whose role includes 'facilities management tasks' contacts the Estates department. The Estates department is perceived to be helpful although they are unable to respond immediately to the problems in Case Study 2. One source of dissatisfaction is the automatic operation of windows. Windows open in weather adverse conditions (rain/draft/cold) and interfere with activities in the office. The technician felt that the building management activities should take place onsite for a more efficient operation of the building. Table 3 summarises the key findings concerning facilities management aspects and institutional policies and norms that enabled (or discouraged) the adaptation actions.

Table 3 Summary of facilities management aspects and corporate support to initiatives

Case Study	1	2	3	4
BMS	No BMS	BMS off-site, by internal organisation	BMS onsite, problems-data corruption	BMS off-site, by external organisation
FM's role	No FM/office manager	FM Off-site, technician onsite troubleshooting	FM on site, troubleshooting	No FM/ caretaker, troubleshooting
*Corp. pro-comfort	Yes, reason: productivity	Neutral	No: reputation, aesthetics, safety	Neutral
**Corporate pro-EneEffic.	No	Reduction of electricity use	No	Reduction of electricity use

*Corporate norms/policies that supported initiatives to achieve comfort; **Corporate norms/policies that supported initiatives to reduce energy consumption

Discussion and conclusions

The research data suggest that occupants are willing to modify their thermal conditions through personal adaptation and by using building technologies/features (windows/doors). This is manifest in the following strategies: (1) rearrangement of the space (dynamic use and location of workstations in relation to individual thermal preferences in Case Study 1); and, (2) Adaptation actions observed in all of the case studies, in alignment to the thermal comfort theory (Brager and De Dear, 1998). However, the data also suggest that corporate policies could support (and discourage) the adaptive opportunities available to occupants. In Case Study 1, the company supported actions to achieve comfort to enhance employees' productivity. In Case Study 3, corporate norms limited adaptation: restricted dress code, restricted operation of windows/blinds. In Case Study 4, the opportunities to operate the windows were restricted by the change of use in a space originally designed as a ventilation area. The organisational context, therefore, could potentially have an effect on the scope of individual and adaptation actions available to building occupants. In other words, the actions for comfort and the operational practices at facilities management level (and alike- ie. caretaker) took place against a background of institutional policies and norms. The range of the actions available to different stakeholders (occupants, facilities managers) seemed to vary in relation to the institutional context. It should be noted that the management and the operation practices were not driven by energy and environmental targets in the case studies. Case Study 3 had a facilities manager onsite who did not exert direct actions for energy and environmental management. In one case study, the facilities manager was located offsite and in two case studies there were no facilities managers in house. There was a general opinion that facilities management was a reactive rather than the proactive role needed to enhance the energy and indoor environmental performance or to foster the efficient operation of the buildings.

This work has provided insights into occupants' actions and facilities management practices in relation to institutional norms and policies. The results draw attention to the complex context of building use and operation and question the simplistic notions that regard the user as a passive agent and the stereotypical user as a standard 'concept'. Ultimately, the paper advocates a more sophisticated understanding and more nuanced representations of users, in contradiction to the typical 'one size fits all approach' to inform energy efficiency interventions and strategies to improve the operational performance of existing buildings. Such a need is already recognised by service design approaches for the design of many new buildings, when the concept of 'personas' prevalent in user-centred product and technological system design is used to explore possible interactions between different types of users and the managed buildings they will inhabit. The acknowledgement of the agency, the knowledge and the non-arbitrary actions of building occupants within the context of organisational norms and policies are key propositions to analyse the 'counterintuitive' and 'inefficient' occupant behaviour. That stance puts inhabitants at the centre of the debate to achieve energy and environmental performance targets in existing buildings. Their different perspectives could inform interventions guided by the concerns and needs that are relevant to the users with a view to enhance the energy and environmental performance of existing buildings.

Further research will examine how corporate goals and individual goals could be linked to energy efficient intentions. For example, it is widely recognised that good indoor environments have positive effects on occupants' health and wellbeing: increased productivity, reduced absenteeism, better educational attainment. These aspects are likely to be relevant to occupants' concerns and corporate goals and could be nudging points to motivate the proactive and efficient management of building performance. The energy efficiency initiatives in non-domestic buildings seem to sit within three layers of action: building occupants, facilities management and the organisation/corporate level. Aligning the different visions of these stakeholders may result in more effective ways of operating buildings. This could provide feedback to designers to enhance their understanding of operational performance and to inform the design representations of occupants.

Limitations

The user studies aimed to explore the indoor environment variations experienced in the buildings throughout the year and within the day of the visit (morning and afternoon) by investigating the participants' responses in relation to the specific indoor environment conditions of the day of the visit. They are not representative of the season. The user studies investigated the occupants' actions and facilities management practices that take place within the organisational policies; aspects that are relevant to the achievement of energy and environmental performance targets in existing non-domestic buildings.

References

BRAGER, G. S. & DE DEAR, R. J. 1998. Thermal adaptation in the built environment: a literature review. *Energy and buildings,* 27**,** 83-96.

COLE, R. J., BROWN, Z. & MCKAY, S. 2010. Building human agency: a timely manifesto. *Building Research & Information,* 38**,** 339-350.

FEDORUK, L. E., COLE, R. J., ROBINSON, J. B. & CAYUELA, A. 2015. Learning from failure: understanding the anticipated–achieved building energy performance gap. *Building Research & Information,* 43**,** 750-763.

INALHAN, G., BROWN, Z., COLE, R. J., ROBINSON, J. & DOWLATABADI, H. 2010. Evaluating user experience in green buildings in relation to workplace culture and context. *Facilities,* 28**,** 225-238.

JANDA, K. B. 2011. Buildings don't use energy: people do. *Architectural Science Review,* 54**,** 15-22.

KRIPPENDORFF, K. 2006. The semantic turn: a new foundation for design. *ARTIFACT-ROUTLEDGE-,* 1**,** 51.

LORCH, R. 2008. *Buildings, culture and environment: informing local and global practices*, John Wiley & Sons.

VAN DRONKELAAR, C., DOWSON, M., SPATARU, C. & MUMOVIC, D. 2016. A review of the regulatory energy performance gap and its underlying causes in non-domestic buildings. *Frontiers in Mechanical Engineering,* 1**,** 17.