TECHNICAL FEATURE

Interviews with Building Operators

How Occupants Affect Building Operators' Decision-Making

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Building operators and facility and energy managers of large buildings make essential operational decisions that affect energy and comfort performance. For example, they decide on the hours of operation of an air-handling unit, default zone temperature settings and outdoor airflow rates, largely based on assumptions about a building's occupancy and occupant preferences. This article reports the preliminary results of a larger effort to understand the operational decision-making process of building operations staff.

We conducted interviews with building operators, facility, and energy managers from different organizations. Despite the fact that some previous research studies used operator interviews (such as the International Facility Management Association pilot survey on facility performance feedback[1]), our focus is primarily on understanding operators' perceptions regarding occupancy and occupant behavior. Unlike previous work, these interviews provide insights on how operations staff handle uncertainties related to building use and occupant expectations, as well as how they use emerging sensing technologies and data analytics solutions that provide insights into occupancy and occupant preferences in their decision-making process.

Questionnaire, Participant Recruitment and Interview Process

The questionnaire presented in this article was developed in discussion with expert researchers participating in the International Energy Agency's Energy in Buildings and Communities Programme Annex 79.

The interview consisted of 22 questions, incorporating a range of topics related to energy management and occupant comfort. The interview started with some basic questions, for instance, interviewees' official title,

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their relevant experience/credentials; and ended with questions to understand their views about occupant comfort needs and motivations toward their operational decisions. We also sought to identify the nontechnical challenges building operators face in improving energy efficiency in their facilities.

Interview participants were selected based on their expertise and involvement in building operations and facility management. Seventeen interviewees from five different organizations participated.

Building Information and Operational Details

The buildings managed by the interview participants are mostly office, institutional and multifamily residential buildings. The participants are responsible for managing between five and 160 buildings. These buildings are diverse in nature, typically between new and 50 years old. The buildings are either equipped with variable air volume systems or constant air volume systems; the older ones are pneumatically controlled, and the newer ones use direct digital controls. Most of the operators of old buildings noted that they suffer from insulation problems as a result of the deterioration of the building envelope. Also, they noted it is not often possible to provide users with access to certain features such as adjusting the thermostat setpoint since these features are not compatible with the old buildings' automation systems.

However, the positive side is that many of the interview participants were found to be motivated to implement energy-efficiency strategies in their buildings. The use of district energy systems to reduce greenhouse gas (GHG) emissions and the application of geoexchange systems and heat recovery for heating and ventilation, respectively, are some of the examples of energy-efficiency strategies being used in their managed buildings.

As part of the interview, participants were encouraged to share facility management and building operation-related photographs as well as pictures of dashboards that visualize buildings' operational performance. *Figure 1* shows an exemplary building operations room for around 50 buildings. This room encompasses real-time visualization facilities of the buildings' key performance indicators; a workstation for bench testing devices, configuring controllers, sensors, actuators; and designated desk arrangements for the building automation system (BAS) operators and an energy metering technician. The BAS operators are responsible for providing building energy and comfort-related operational decisions based on occupant schedule, occupant complaint logs and weather conditions.

FIGURE 1 Operations room for around 50 buildings. This is an example of a photo submitted by a participant.

Traditional Decision-Making Processes

The traditional building operational decision-making process involves uncertainties associated with building energy use and occupant comfort. To understand how building operations staff tackles these uncertainties, they were asked to give opinions on the relevant questionnaire items. For instance, they noted their own personal demands for comfort and how this influences their operational decisions. A few interview participants indicated that they do not want to impose their personal comfort expectations on occupants; rather, the main driver of their operational decisions is to improve occupant comfort. In contrast, most of the participants reported having a slight bias toward their personal experience and being self-motivated to implement energy-efficiency measures without compromising occupant comfort.

The participants reported that occupants usually make service calls when they feel uncomfortable with the indoor environment. Additionally, the participants stated that occupants tend to adapt their indoor environments to improve their comfort level by changing their clothing levels; blocking the heating system; using electric heaters, fans and portable air conditioners; and delamping.

Interview participants reported restricting occupant adaptation to the indoor environment to a certain extent. They do this by either locking the windows or thermostats, or at least limiting the controllability of the thermostats to a maximum of 1°C–2°C (2°F–4°F). One participant cautioned that occupants often keep the windows open even when it is not required, to the detriment of heating and cooling energy, and reported being receptive to allowing occupants to open a certain percentage of windows based on the outdoor temperatures. However, many interviewees noted that they use separate lockboxes in the multi-occupant rooms or common spaces to prevent users from fighting over temperature setpoints. They also do this to prevent occupants from misusing these building systems.

While the interviewees were split on whether or not giving occupants more control may help improve occupant comfort, all were hesitant about implementing any sort of occupant-centric controls ranging from simple presence-based switching of lighting systems to full model predictive control,[2] due to the perceived lack of evidence that they could be executed without negatively impacting energy performance.

Most interview participants indicated that hot and cold complaints are the most frequent complaint type in their facilities. They usually receive this type of complaint year-round, though more frequently in extreme conditions. Participants noted more frequent complaints during the switchover period from heating to cooling and vice versa. Thermal complaints increase in prevalence in the mornings after operating the buildings in free-cooling mode.

When asked about the frequency of communicating with building occupants, most energy management personnel reported they usually indirectly communicate with occupants via their subordinates or the building technicians on a daily or weekly basis. Sometimes facility managers receive online comfort-related feedback directly from the tenant representatives. Before starting a renovation project or if there are any action-oriented special issues, the facility managers visit and communicate with building occupants in person. On the other hand, building operators usually communicate with building occupants daily or at least three times a week.

Regarding nontechnical challenges the participants face in improving energy efficiency in their facilities, most participants said that dealing with finances is the most challenging part of executing any renovation or retrofit work in their facility. Participants also reported that they encounter the challenge of motivating occupants to undertake energy-efficient behaviors, as well as tackling the constraints of the HVAC control system with occupant expectations and engaging occupants in occupant comfort survey. Energy manager participants noted that building operators are often stuck in their own ways and are not always keen to adapt to new technology.

The interview identified the issue of "energy champions" in the energy management sectors as a barrier to successful implementation of energy-efficiency strategies in their facilities. This problem is well supported by the statement made by Hooke, et al.,[3] that overreliance on a single energy champion is risky. Sometimes, the so-called energy champion does not want to implement energy-efficiency strategies in their facilities because they know there is a risk of poor execution and resulting comfort consequences.

A few other nontechnical challenges were also identified through this questionnaire survey. These include dealing with procurement, leadership issues in the operations team, a communication gap between energy and operations team, motivation toward customer service and technological knowledge enhancement and execution of long-term strategic plan.

Participant Responses

Figure 2 presents an overview of responses for some of the questionnaire items regarding participants' perception of occupant needs and comfort and their attitudes toward various operational performance goals.

Figure 2a shows that the majority of interviewees believe their managed buildings' occupants are comfortable. However, as the use of spaces changes over time, sometimes it becomes difficult for them to satisfy occupant comfort. Five interviewees expressed mixed feelings regarding their understanding about the needs of building occupants. This is because of conflicting information coming from occupants. Several of these interviewees noted that yearly or quarterly comfort surveys reflected lower than expected occupant satisfaction within buildings, even when complaint calls are minimal between surveys. They postulated that by offering such sporadic surveys, occupants seize this limited opportunity to "lash-out," as smaller issues can fester during this time.

Additionally, collocating the type of complaint and the exact location within the building presents an organizational and technological hurdle when trying to address localized problems (e.g., drafts, glare, etc.). One participant expressed a desire for a way to gather consistent, nonintrusive occupant feedback at a granular level to overcome these problems and begin to build a comfort benchmark for their buildings using these data to identify where additional operational resources should be allocated.

Four participants feel they understand the needs of building occupants very well. This interview made an effort to reveal relevant anecdotes behind this assurance. One interview participant mentioned, "I received many cold complaints from the occupants, but the thermostat indicated the temperature was within the comfort zone. Then, I identified the root cause; it was the high indoor air velocity, which made people uncomfortable even though the air balancing report did not show any abnormalities." This indicates that occupant feedback sometimes can misguide building operators, and the best solution in that case is to take the help of historical data/BAS trend log.

Only one participant reported understanding the needs of building occupants poorly. This participant mentioned the difficulty of administering occupant comfort surveys as a cause; a majority of occupants do not want to participate in the survey.

FIGURE 2 Overview of participant responses to four questions.

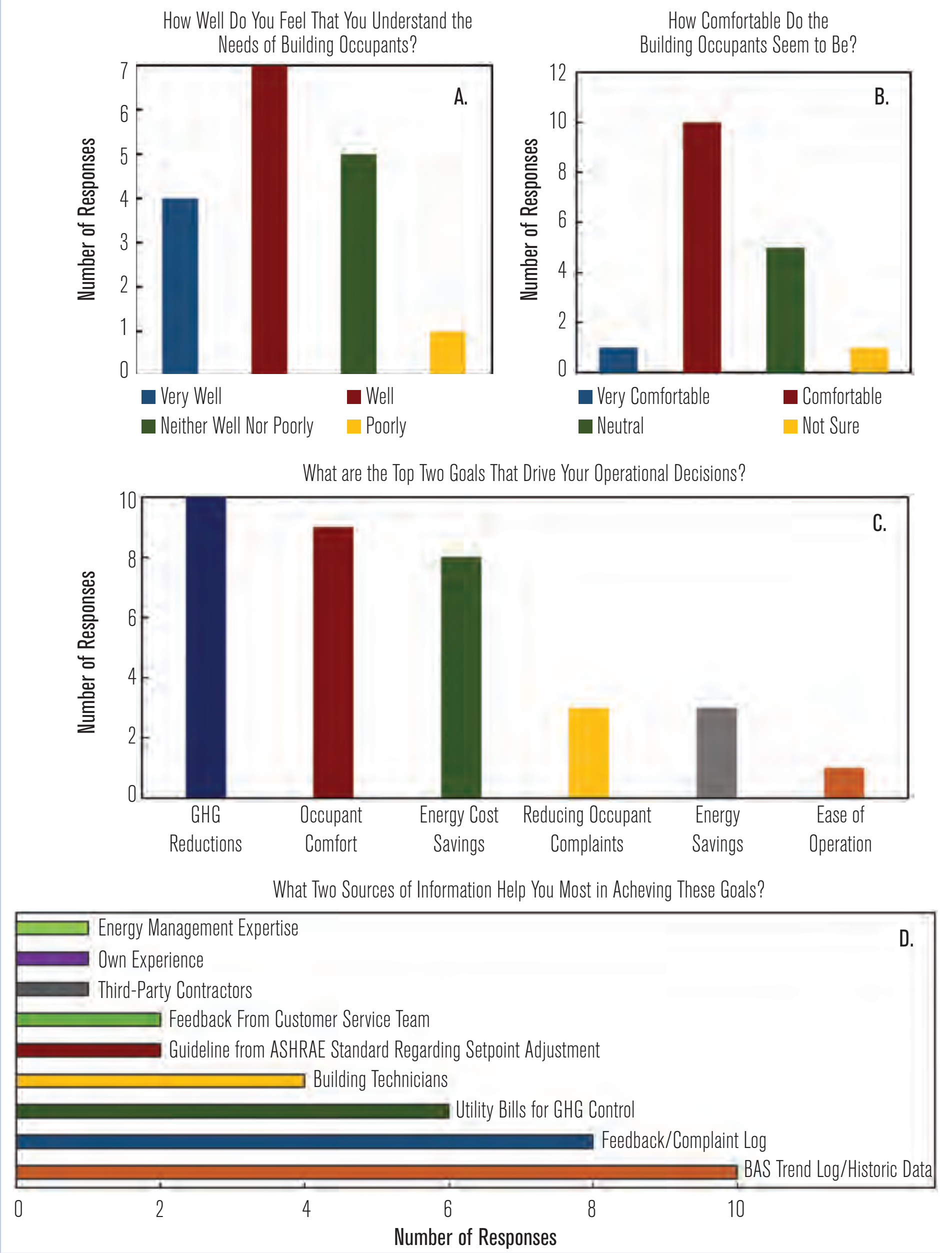

Figure 2b shows that 10 participants believed the occupants of the buildings they manage are satisfied with the indoor environment. The second-highest number of participants (five) gave a neutral opinion. The interviewees mentioned that since some of their managed buildings are quite old, natural wear and tear issues are involved that cannot be solved completely through operational measures alone, and this impacts buildings' indoor environment. Also, one occupant reported, "Our glass-walled buildings' heat gain or heat loss related issues are partly responsible for not achieving occupants' desired comfort."

It was found that the majority of interviewees believed that they are doing all they can given the current condition of their buildings; building operations are regarded as near-optimal, and the only way to improve the buildings' performance is to make major investments such as envelope retrofits. While this may be true in select cases, in many cases some major underlying operational issues may exist that cause discomfort and deteriorate energy performance. It is likely that interviewees who provided this kind of response do not have access to adequate building operations data or occupant feedback to facilitate improvements in their operational decision-making process.

This interview revealed important findings regarding interview participants' top two goals that drive their operational decisions (*Figure 2c*). Many participants chose certain responses (top two goals) as they acknowledge contractual obligations. However, a few interviewees noted they have a separate and conflicting set of goals (such as reducing occupant complaints and improving energy efficiency or reducing occupant complaints and energy cost saving) that they believe are important for making their operational decisions.

As shown in *Figure 2c*, GHG emission reductions and occupant comfort are the top two goals that drive most of the interview participants' operational decisions, and this is based on their contractual obligations set by building owners.[4] (In Canada, where interview participants work, facility managers are required to maintain the mechanical environmental standard for federal office buildings, and as part of this obligation, they need to fulfill explicit GHG emission targets.)

Figure 2d presents sources of information that help the interview participants most in achieving their operational goals. The highest number of participants (10 out of 17) think that BAS trend log/historical data is one of the two most important sources of information that assist them to achieve their goals, followed by occupant surveys (feedback) and complaint logs, utility bills for GHG emission reductions and building technicians.

For these interviewees, their ideal solution is analytics platforms for automatic fault detection and diagnostics. This tool is only useful to them if it can have a simple visual interface and, most important to them, quantify the energy implications these faults have on their building portfolio. The ability to circulate these findings to people within their organizations from technical and nontechnical backgrounds is critical to ensure that the urgency of these issues is given credence and that operational faults are addressed in a timely and appropriate manner. However, most of the participants personally believe that their own experience is the primary source of information that assists them in achieving their goals.

Use of Sensing Technologies and Data Analytics Solutions In Operational Workflow

It was found that facility managers and operators are quite familiar with CO_2 sensors even though their managed buildings are typically controlled based on a fixed occupancy schedule. In some specific locations (e.g., gym, meeting room, parking garage, boiler rooms) CO_2 sensors are used. Also, they reported that in some new or newly renovated buildings, CO_2 sensors are widely used for HVAC control. Also, buildings that operate 24/7 were reported to have CO_2 sensors that are used to efficiently control the ventilation strategies. On the other hand, traditional motion detector-based occupancy sensors were found to have limited use for HVAC controls. In some locations such as laundry rooms, lounges, etc., these sensors are used for lighting control.

Table 1 presents an overview of some of the open-ended questionnaire items and responses for which participants were not given a list of options from which to choose.

According to the responses for the first question shown in *Table 1*, data archiving/logging capability is the most important feature of a BAS to the majority of interview participants. Some other important features of BAS as per participants' interview survey are shown in *Table 1*. A BAS is generally used in their managed buildings to automatically adjust the setbacks and ventilation rates based on occupancy schedules. However, participants noted that during extreme conditions they override the automation and maintain a longer lead time to maintain the temperatures at the setpoint. Also, to overcome the problem of heat loss/heat gain because of the deterioration of the building envelope, one participant mentioned, "In some of my managed buildings, a longer lead time (approximately two to three hours) is maintained for the air-handling units in the morning time."

TABLE 1 An overview of the questionnaire items and responses. (Please note in some cases more than one response was received from one participant to a survey question.)

WHAT BAS FEATURES ARE MOST IMPORTANT TO YOU?	No. of Responses
Data Archiving/Logging Capabilities	11
Online Monitoring and Troubleshooting	2
Track the Performance of HVAC Equipment	1
Implement Smart Building Initiatives in Collaboration With Third Party Through Data Sharing	1
Remote Access to Automation System	1
Zone-Wise Temperature Information	1
Local Control of Temperature Setpoint and HVAC Equipment	1
HOW COULD YOU USE 'REAL-TIME' OR ARCHIVED INFORMATION FROM THE BAS TO MAKE OCCUPANTS MORE COMFORTABLE?	**No. of Responses**
Identify HVAC Equipment Fault Before it Impacts Occupant Comfort	9
Minimize HVAC Equipment Maintenance by Identifying Root Causes of Major Faults	4
Control the Ventilation System More Effectively by Linking Real-Time Occupancy Counting Data with Temperature and CO_2 Sensor Data	1
Predict Ahead of the Comfort Issues by Looking At the Trend of Complaints and Archive Data	1
Receive Services from Third Party Such as Indoor Air Quality Consultant by Sharing "Real-Time" or Archived Information from the BAS	1
Identify Any Abnormalities Associated with HVAC Control at the Initial Stage	1
WHAT IS THE MOST IMPORTANT INFORMATION THAT YOU WISH YOU HAD ACCESS TO REGARDING OCCUPANTS AND OCCUPANT COMFORT?	**No. of Responses**
Building Occupancy Count Data	6
Detailed Feedback from the Occupants	5
Zone-Wise Occupancy Presence Data	4
Day-Ahead Occupancy Pattern Forecast Data	1
Occupants Perception of Comfort	1
HOW WOULD YOU BENEFIT FROM HAVING ACCESS TO OCCUPANTS AND OCCUPANT COMFORT-RELATED INFORMATION?	
Take Part in Energy Savings by Adjusting Ventilation Strategies Based on Real-Time Occupancy Data	
Improve Occupant Comfort and Reduce Occupant Comfort Complaints	
This Occupancy Presence Data Could be Used to Cut the Power Supply When Occupants are Not In	
Schedule Major Hot Water Uses Based on Occupant Demand	

In response to the question in *Table 1* about how the participants could use "real-time" or archived information from the BAS to make occupants more comfortable, the highest number of participants mentioned identifying HVAC equipment faults before they impact occupant comfort. A few participants said that by using this information they could identify the root causes of major HVAC equipment faults and, thus, minimize equipment maintenance costs.

Figure 3a presents an example of start and stop schedules of temperature setpoints and ventilation rates during the summer for one of the participants' facilities. The schedule shows different start and stop times during weekdays and weekends. It demonstrates an example through which operator decisions influence energy and comfort performance. This questionnaire survey anecdotally revealed that the typical start and stop schedules of air-handling units largely depend on occupancy hours as well as outdoor temperature and peak and off-peak electricity demands.

All participants reported they maintain a specific summer and winter setpoint during these seasons even though dead band is not maintained in all of their managed buildings; some buildings require manual adjustment of the setpoints, as the system does not have that feature. In this regard, one participant said, "When the outdoor air temperature is extreme, I try to maintain a minimum outdoor air ventilation rate and thus, I optimize outdoor air heating and cooling energy consumption."

This interview reveals there are differences in summer and winter setpoint ranges adjusted by different facility managers, and in most cases their adjusted setpoints do not align with ASHRAE Standard 55-2017.[5]

FIGURE 3 Participant dashboard examples. (a) weekly operating schedule of a building; and (b) tenant-level electricity use dashboard to flag energy use anomalies.

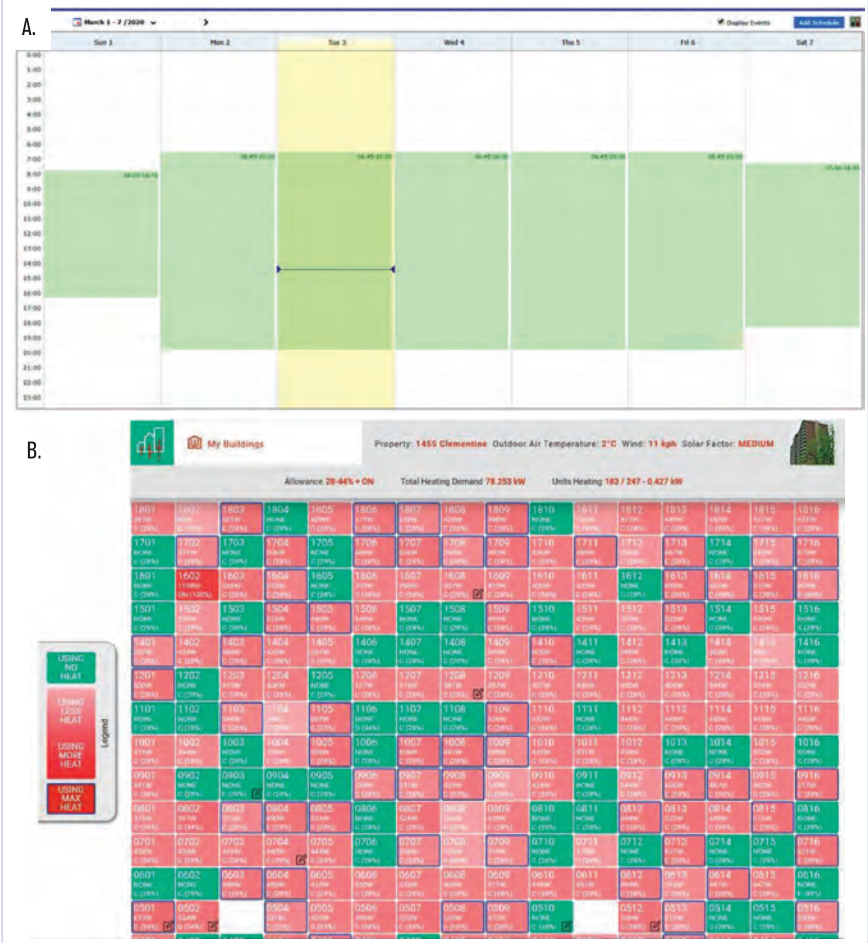

Figure 3b shows a dashboard that highlights tenant-level energy uses. Through this dashboard, one of the participants visualizes the diversity in tenant-level energy use and identifies high energy consuming units. The participant reported using this information along with weather data to control the operation of HVAC equipment.

Regarding the question in Table 1 about occupants and occupant comfort-related information, the participants wished to have access to building occupant count data, detailed feedback from the occupants, and zone-wise occupant presence data. The participants also discussed some comfort and energy saving benefits to having access to occupants and occupant comfort-related detailed information.

Recommendations and Research Needs

The interview results show that building energy management personnel and operators are enthusiastic about receiving advanced occupant sensing technologies and are passionate about meeting additional operational goals through implementation of occupant-centric building controls in their managed buildings, regardless of the issue of energy champions. However, they often need to go through multiple nontechnical (e.g., interpersonal, organizational) challenges while exercising energy-efficiency strategies in their facilities. To overcome these challenges and to execute any comfort and building performance-related long-term strategic plan, it is necessary to ensure wholehearted engagement and cooperation of building operators and occupants, along with government support. Also, researchers need to demonstrate that facility managers can execute energy-efficiency strategies in their facilities without any negative impacts they fear (such as a risk of poor execution, which can impact occupant comfort).

On the other hand, building operators should pay more attention to adjusting the setpoint temperatures and maintaining a different setpoint range for the summer and winter. The fact that operators do not seem to rely on ASHRAE Standard 55-2017 necessitates further investigation.

Occupant feedback is recognized as the vital component to ensuring a building's ability to fulfill the functions of its intended use.[6] However, based on this interview outcome, we argue that sometimes occupant complaint logs and detailed feedback are not sufficient to detect the root cause of any unsatisfactory indoor environment. In such cases, building operators need to supplement occupant feedback with BAS trend log/historical data. This is a drawback of relying on occupant feedback alone to detect the fault of HVAC equipment, which determines the need for implementing data-driven operational strategies such as automatic fault detection, and predictive and occupancy-centric controls.

Some participants mentioned that they look at BAS trend logs to diagnosis the root cause of complaint calls from occupants. However, they still experience the difficulty of identifying operational faults since they need to deal with large amounts of data from multiple buildings. This highlights the need for further research on simplifying the whole fault detection process through implementation of advanced-level analysis of HVAC control data, meter data, lighting data, etc., and to present the results in an interactive dashboard.

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