

# UC Berkeley

## Indoor Environmental Quality (IEQ)

### Title

A web-based POE tool for measuring indoor environmental quality

### Permalink

<https://escholarship.org/uc/item/56s462z4>

### Authors

Zagreus, Leah  
Huizenga, Charlie  
Arens, Edward

### Publication Date

2004-04-29

Peer reviewed

## **A Web-based POE Tool for Measuring Indoor Environmental Quality**

**Ms Leah Zagreus, MIMS, Center for the Built Environment**

**Mr Charlie Huizenga, MS, Center for the Built Environment**

**Prof Ed Arens, PhD, Center for the Built Environment**

**Keywords:** building science, buildings, POE, occupants, surveys

### **ABSTRACT**

The Post Occupancy Evaluation (POE) process provides necessary feedback to the building industry, fostering the improvement of existing facilities as well as contributing to knowledge that improves the planning, design, construction and operation of future facilities. Surveys of building users are a key component of successful POEs. The Center for the Built Environment (CBE) at the University of California, Berkeley, has developed a Web-based survey that can quickly and inexpensively collect occupant perceptions about the environmental quality of the workplace, as well as opinions of other audiences involved in the design, construction and maintenance of the facility. The growing database of standardized survey responses can be analyzed for trends in building technologies and design techniques. CBE has developed and continues to develop tools that facilitate the analysis and display of the data collected by the survey. Case studies demonstrate that the survey has been effective in helping pinpoint problems.

### **1. INTRODUCTION**

The Post Occupancy Evaluation (POE) process provides necessary feedback to the building industry, fostering the improvement of existing facilities as well as contributing to knowledge that improves the planning, design, construction and operation of future facilities. Surveys of occupants and other audiences involved in the use, creation and maintenance of buildings are an essential information-gathering piece of successful POEs. Web-based surveys can quickly and inexpensively collect these opinions and display the results. Performed in a standard way, the data gathered from these surveys can be compiled in a knowledge base for analysis of trends with respect to building technologies, materials and design techniques. A research group at the University of California, Berkeley (UCB), the Center for the Built Environment (CBE), has developed such a survey and knowledge base. The survey has been extensively tested and refined, has been conducted in more than 70 buildings to date, and the database of surveyed buildings is growing rapidly, creating a repository of standardized survey data. A sophisticated online reporting tool allows the results to be viewed and analyzed immediately upon close of the survey. A building's performance can only be understood in the context of other buildings, and so CBE is developing specialized data analysis tools that will allow the survey results for buildings (or sets of buildings) to be compared to one another. Using information visualization techniques, the tool will facilitate exploration of how well certain design decisions or technologies work in practice.

The survey has been demonstrated to be effective in helping pinpoint problems (alone and as a tool within a complete POE process). Although the benefits to conducting POEs are clear and demonstrable, obstacles are to be overcome before their use is widespread.

## **2. FEEDBACK FOR BETTER BUILDINGS**

Comprised of faculty and researchers at UCB, and supported by the National Science Foundation and public- and private-sector industry partners, CBE works to inform the building industry about new building technologies and design techniques. A core tenet of CBE is that everyone in the building process benefits from learning how a building actually performs in practice.

POE surveys are an important way of providing feedback to the participants in the building industry. Survey results can be used as diagnostic information for identifying specific problems in a building or for longer-term goals such as providing feedback to designers (Zimring and Rosenheck 2001; Leaman 2003).

Occupants' opinions give us important information about how a building is actually performing from the perspective of those who use the building. As noted in a report by the U.S. Federal Facilities Council (FFC), POE "is based on the idea that better living space can be designed by asking users about their needs." The Probe studies have shown that there is a direct relationship between worker comfort and self-reported health and productivity (Leaman and Bordass 2000).

If it's important to provide a comfortable environment for occupants, and occupants are uniquely qualified to report on their own comfort, why haven't surveys been more prevalent? Clearly the traditionally high cost of implementing surveys is one reason, but a number of additional barriers prevent their widespread use (Zimring and Rosenheck 2001; Leaman 2003).

## **3. THE CBE SURVEY**

Researchers and faculty at CBE have backgrounds in mechanical engineering, architecture, information management, and software development. This multi-disciplinary group, well versed in building science as well as usability issues, has developed a Web-based indoor environmental quality (IEQ) survey<sup>1</sup> to inexpensively measure occupants' perception of the quality of their workplace environment.

The CBE survey tools address many of the problems noted by Zimring and Leaman:

- The Web-based survey format provides a way to quickly gather and report information from occupants, designers, and operators at considerably lower expense than paper surveys.
- The growing database of standardized survey responses affords the opportunity to discover trends in building technologies and design strategies as well as how these technologies and strategies impact the occupant.
- Individual occupants or buildings are protected from identification because findings are presented in aggregate.
- Our consortium of industry partners is committed to learning from one another and putting the group's findings into practice.
- One of the benefits of CBE partnership is the ability to compare individual results against the growing benchmark database. While overall results are made publicly

---

<sup>1</sup> See [www.cbosurvey.org](http://www.cbosurvey.org) for a demonstration version of the CBE occupant IEQ survey.

available, we hope that such incentives will help to keep the survey project and CBE research consortium afloat.

Prior to Web-based surveys, creating, distributing, and analyzing paper questionnaires was a time-consuming and expensive process, and diagnostic paper surveys necessarily took a long time for occupants to complete. In addition, surveys have tended to be project-specific and not often repeated. One exception is the Probe study in which a standardized survey was used to benchmark building performance (Leaman et al 1997) for a large number of energy-efficient buildings. The CBE Web-based survey is similarly standardized and focused on IEQ, but by being Web-based, it offers two additional benefits. First, it can be inexpensively administered to many buildings. Second, its interactive branching questions allow it to “drill down” into areas that the occupants rate poorly, and thus in many cases diagnose the root of the problems.

### **Survey Content and Design**

The occupant survey is comprised of a core survey and optional survey modules. Each organization using the survey has the option of employing the core survey or customizing the survey with additional modules that address special issues not covered in the core questions. The core questions assess occupant satisfaction with the following IEQ areas: office layout, office furnishings, thermal comfort, indoor air quality, lighting, acoustics, and building cleanliness and maintenance. Examples of optional modules include wayfinding, safety and security, operable windows, shading systems, floor diffusers, and washrooms. Core questions stay consistent for each implementation to maintain data integrity for the purposes of benchmarking and trend analysis. The survey uses a 7-point scale to gauge satisfaction with the survey areas. Other question formats (e.g., radiobutton, check-all-that-apply, etc.) collect background demographics and other information about the workspace.

The survey instrument has been extensively tested and refined, and facility managers and designers have evaluated the reporting format to determine the utility of various report designs. The Survey Research Center at UC Berkeley used an established method called “cognitive interviewing” to assess how well respondents were able to comprehend and accurately report answers to survey questions (Eisenhower 2000). Cognitive interviews allow researchers to examine the thought processes that affect the quality of answers provided to survey questions. The primary technique used was the “concurrent think aloud” method whereby each respondent was asked to comment out loud about anything crossing his or her mind while reading, interpreting and answering each question. Results were used to refine the survey organization, question text, graphic design of the scales, and the process of accessing the survey Web site.

Occupants typically complete the core survey in 5 to 12 minutes, although this time varies depending on the number of branching questions and the extent of comments. In some of our initial implementations, we included a question about the survey length; less than 20% of respondents indicated that the survey was too long. Surveys that include several customized modules in addition to the core survey have had completion times of up to 20 minutes. Organizations that choose to implement longer surveys are briefed regarding the potential negative effect that longer surveys can have on response and completion rates.

### **Customization for Specific Information Needs and Survey Audiences**

The flexibility of the underlying survey architecture makes it relatively easy to add new or existing modules to the core survey to suit the needs of a particular project or client. Although we originally developed the survey to gather feedback from building occupants, we have also developed two additional instruments to collect the opinions of other audiences involved in the use or creation of the facility. The first is an operations and maintenance staff survey that evaluates staff satisfaction with the design and construction of the building and its effect on their ability to run and maintain the facility. The other instrument is a design and construction process survey that addresses issues such as communication, project management and decision-making.

### **Multilingual Capabilities**

The occupant IEQ survey has been used in buildings in Europe as well as North America. The survey and accompanying online report can be offered in any language. Clients can conduct the survey in multiple languages simultaneously, with respondents choosing the desired language at the time they access the survey Web page. The foreign language questions have been mapped to the English ones so that comparisons of the responses from different buildings can be made regardless of the language in which the survey was taken. To date the survey has been translated into Finnish and Danish.

### **Survey Structure**

The survey was designed for visual clarity and minimal download times. The survey pages are short, reducing the need for scrolling, and are comprised of familiar HTML form controls generated dynamically using Microsoft's ASP and JScript technologies, and client-side JavaScript. The graphics are simple and the controls and typefaces are clearly laid out and easy to read. A progress bar at the bottom of each page indicates how much more of the survey remains. The survey is compliant with the Americans with Disabilities Act, and can be used with a screen reader for the visually impaired.

Occupant responses are collected via the Internet and recorded to a secure Microsoft SQL Server 2000 database (SQL is a standardized query language for storing, retrieving and modifying information in a database). The survey works with multiple browsers and does not use cookies, session variables or other Web development techniques that can hamper functionality for some users.

### **Survey Implementation**

The occupant IEQ survey implementation process typically begins with an email informing building occupants of the survey Web site address, and the start date and end date (surveys typically stay open for 1-2 weeks). This email is drafted and sent either by CBE or the sponsoring agency. Subjects can access the survey at their convenience by clicking on the link in the email invitation. After linking to the survey using a Web browser, respondents see a welcome screen informing them of the purpose of the survey, the sponsoring agency, and how the results will be used. The welcome page also advises them of the amount of time it should take to complete the survey, and their rights as a research participant. Participation in the survey is voluntary and anonymous, and respondents may opt out at any time. Upon starting the

survey, participants click through a series of questions asking them to evaluate their satisfaction with different aspects of their work environment (Figure 1).

**Acoustic Quality**

---

**How satisfied are you with the noise level in your workspace?**  
 Very Satisfied        Very Dissatisfied

---

**How satisfied are you with the sound privacy in your workspace (ability to have conversations without your neighbors overhearing and vice versa)?**  
 Very Satisfied        Very Dissatisfied

---

**Overall, does the acoustic quality in your workspace enhance or interfere with your ability to get your job done?**  
 Enhances        Interferes

Survey Progress...

All contents copyright © 2000-2004 The Regents of the University of California. All rights reserved.  
Revised: July 11, 2003

**Figure 1. Sample occupant IEQ survey page.**

Satisfaction is rated on a 7-point scale ranging from “Very Satisfied” to “Very Dissatisfied,” with a neutral midpoint. In most cases, respondents who indicate dissatisfaction with a particular aspect of their work environment are “branched” to a follow-up screen probing them for more information about the nature of their dissatisfaction (Figure 2). Respondents who indicate neutrality or satisfaction (the upper four points on the scale) move directly to the next survey topic. Dynamically tailoring the survey in this fashion enables diagnostic information to be gathered about potential problems in the building, and keeps questions relevant to each respondent while making the survey as succinct as possible.

When applicable, respondents are also asked to assess the impact of environmental factors on their effectiveness in getting their job done, as shown in the last question in Figure 1. The advantage of the CBE productivity question phrasing is that it essentially answers two questions at once – first, whether the respondent believes that the item impacts their job performance, and also implicitly how important the item is perceived to be.

**Acoustic Quality (continued)**

---

**You have said you are dissatisfied with the acoustics in your workspace. Which of the following contribute to this problem? (check all that apply)**

- People talking on the phone
- People talking in neighboring areas
- People overhearing my private conversations
- Office equipment noise
- Office lighting noise
- Telephones ringing
- Mechanical (heating, cooling and ventilation systems) noise
- Outdoor traffic noise
- Other outdoor noise
- Other:

---

**Please describe any other issues related to acoustics that are important to you.**

---

Survey Progress...

All contents copyright © 2000-2004 The Regents of the University of California. All rights reserved.  
Revised: July 11, 2003

**Figure 2. Sample follow-up page.**

### **Advantages of Web Surveys**

Compared to paper surveys, Web surveys are less expensive to implement, easier to distribute, and provide automated and accurate data collection. Kaplan (2001) notes that for these reasons, and because Internet access is becoming increasingly commonplace at home and work, the Web could become the “predominant method of administering building assessments” and could help overcome some of the difficult barriers to conducting a POE, helping to make the assessment more prevalent.

There are a number of other benefits of using the Web. Because reporting is automated, results from the CBE survey are available very quickly. Drill-down questions and comments allow a great deal of diagnostic information to be collected. Branching behavior keeps the survey short and relevant to each respondent. Open-ended comment fields appear frequently throughout the survey, each of which is attached to a particular response, question, or topic. This provides respondents an outlet for any perceptions they might have that are not covered by the survey instrument, ameliorating frustration that might occur from an inability to fully express themselves.

Kaplan describes several components of successful “cybersurveys,” most notably: that the survey be short, quick to download, and clearly and simply designed; that the respondent be given clear instructions for accessing and taking the survey, know the survey close date, and be assured of confidentiality; and that the survey be thoroughly tested and compatible with a variety of Web browsers. As described above, the CBE survey design, infrastructure, and implementation methods comply with these guidelines.

### **Web Obstacles**

Still, some obstacles are to be overcome with Web-based surveys, as Kaplan and the Usable Buildings Trust (2004) note, particularly response rate and availability of Internet access.

#### *Response rate*

Although some people believe response rates from Web surveys may be lower than those from paper surveys, it is likely that other factors have a larger influence on response rate. CBE advocates practices that improve response rates such as survey invitation reminders, participation incentives, and sending the invitation from a highly respected person in the organization.

When a CBE survey is underway, the rate of participation is monitored, and reminder emails may be sent if it is going slowly. Clients also may choose to offer an incentive to encourage respondents to take the survey. Such incentives in the past have been books, cash, government bonds and even vouchers for massage.

Of the buildings surveyed to date, response rates have ranged from 27%-88%, with the majority of response rates between 45%-65%. Overall, response rates are higher when the initial message introducing the survey is sent directly from a person who is well-known and a decision maker within the participating organization. The introductory email for the survey with the lowest response rate was poorly executed; it was forwarded three times before it reached the occupant, each time with an additional header attached. By the time it arrived to the intended recipients, the reader needed to scroll to the bottom of the message to read the original text. This diminished the perceived importance of the study and is likely to have resulted in the low response rate. The study with the highest response rate was introduced with an email sent directly from the head of the organization noting an “important survey” for all building occupants. While likely leading to the high response rate, often this type of cooperation and attention from the head of an organization is difficult to orchestrate. Management sometimes doesn’t see the benefit of participating, though it should be noted that the success of a study depending on buy-in from management is true for paper-based surveys too.

Because we are surveying the entire population of a building, sample rate and selection bias are perhaps less important issues than they are when surveying a small sample in order to extrapolate to a greater population. The people who respond are the ones who have something to say, and arguably provide the responses in which we are most interested. Further, while there may be some self-selection bias, and perhaps dissatisfied occupants are more (or less) inclined to respond, any such influence is



likely to be consistent across surveys. We have found no statistical relationship between response rate and occupant satisfaction in the survey database.

#### *Internet access*

Though Internet access has become increasingly commonplace, not everyone has computers at home, or uses computers for their jobs. Some organizations are reluctant to give employees access as they feel it may be distracting and impact productivity. We have found that in many cases “kiosks” (computers temporarily set up in common areas, or mobile computers) have worked well to gather information from respondents without individual Internet access.

#### **Using the Survey in a POE**

Often a survey is used as part of a one-time project assessment, helping to identify operation or design issues with the building as part of commissioning or re-commissioning (Malin 2003). Surveys can also be used at regular intervals as part of a “continuous commissioning” process (Bordass 2003).

Yet another application of surveys is in pre/post or intervention studies to evaluate the impact of a design change, renovation or new workplace. One survey is implemented while occupants are in the old building or pre-renovated space, and another six months after the occupants have moved into the new building or renovations have been completed. By waiting for occupants to become accustomed to the new space, we hope to minimize the effect that the experience of change itself could have on respondents’ satisfaction levels, and allow for building systems to be fine-tuned. Surveying the same population before and after allows some control over individual differences. It is helpful to control for other variables to the extent possible. Surveying a control group in the organization that is not moving or having their space renovated can also help weed out any biases due to, say, management style (Heerwagen, 2001). Surveying the population multiple times, at different times of year can also help to control for seasonal variation, and adds to the richness of the dataset. It is important, however, to avoid the survey fatigue that can occur by surveying building occupants too frequently.

#### **Objective Environmental Measurements**

In some POEs and field studies, the CBE survey has been used to collect occupant opinions in conjunction with physical measurements data taken simultaneously in the workspace, such as air temperature, radiant temperature, air speed and humidity (Figure 3). This allows for satisfaction and productivity trends to be spotted in response to external environmental stimuli. The data can also be analyzed alongside energy use patterns or other factors. CBE has completed such studies of underfloor air distribution systems, high-performance facades, and operable windows and personal control as it relates to comfort standards (Shirai 2003; CBE 2004; Brager, Paliaga and de Dear 2004). Some of these studies have involved customized, short, “point-in-time” surveys that participants repeat over the course of a few weeks, several times per day and are later merged with the environmental measurements.



**Figure 3. Indoor Comfort Monitor used in Operable Windows field study.**

#### **4. ANALYZING SURVEY RESULTS**

Gathering data is certainly critical, but turning the data into useful information is the goal of a successful POE. Lessons we hope to learn from the data include identifying: existing problems to be fixed in a particular facility; design, construction and operation achievements to carry over (or correct) for the next facility; and which decisions, materials and design approaches tend to result in better facilities with more highly satisfied occupants overall.

Because one of the barriers to successful POEs is fear of punishment for mistakes (Zimring and Rosenheck 2001), CBE presents published findings in aggregate or without identifying information. As Leaman (2003) points out, it is important to take care that we don't suppress innovative designs or promising new technologies with unduly harsh criticism of the implementations if they are not skillfully executed initially. On the other hand it is important not to whitewash problems as a result of researcher bias.

We have developed some promising tools that help us organize survey information in a meaningful way so we can draw conclusions from it. The online reporting tool enables clients to quickly make an assessment of a building's performance and diagnose problems. CBE partners have the option of comparing the building(s) they have surveyed against the entire survey database. Having surveyed more than 70 buildings so far, and with a steady stream of survey implementations, we are creating a repository of standardized data for a wide selection of buildings that can be used as a benchmark. Our ongoing development of exploratory data analysis tools will continue to improve our ability to rapidly analyze building trends.

#### **Individual Building Report**

Data is reported using a Web-based reporting tool, and is quickly made available to clients after survey implementation. The report generation is entirely automated, using the same scripts that generate the survey pages. The report home page summarizes satisfaction ratings for each of the survey categories. This executive summary is particularly useful to decision makers that need to see a top-level overview of occupant feedback. The survey category pages provide charts representing the responses to each of the survey questions (Figure 4). Satisfaction ratings are tabulated for each point on the scale, and are also summarized into three bins: satisfied (top three points), neutral (middle point) and dissatisfied (bottom 3 points). Comments are also displayed for each question. We have learned that reviewers typically scan these

comment lists right after looking at the executive summary page (Baughman et al 1995). To protect the confidentiality of participants, the online report contains only aggregated, anonymous results.

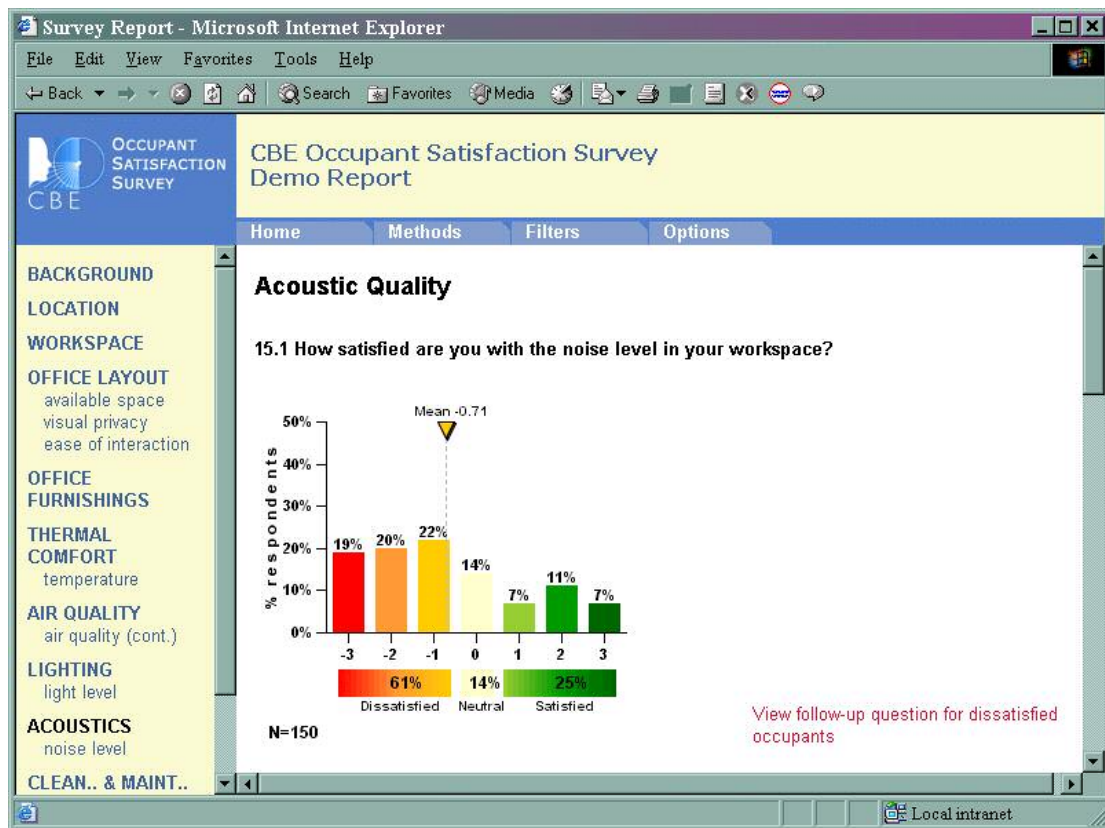


Figure 4. Sample individual building report page.

The report's filtering feature enables users to view relationships between questions. This intuitive feature allows a subset of the responses to be displayed in the charts. For example, perhaps data for occupants who sit near an exterior wall is of special interest: with this filter enabled, the report shows only the data for those respondents who indicated that they sit near an exterior wall. Several filters can be strung together in a Boolean query, further defining the results viewed in the individual building report.

Though the online individual building report has not undergone a formal usability study, feedback from users of the report has been highly encouraging. CBE researchers and other survey clients use the charts and comments in publications to illustrate the results of POEs, field studies or other building evaluations. The U.S. General Services Administration (GSA), for example, uses the CBE survey for a number of projects. In one of these, they are evaluating whether to switch from using a paper-based survey to the CBE Web-based one. Seriously committed to Zimring's "organizational learning," GSA's Public Buildings Service surveys each of their buildings every few years. A number of measures (including an occupant survey) are used to determine how well buildings are performing, and distribution of a pool of bonus money is tied to the results. CBE customized the occupant IEQ survey to include all questions asked by the paper-based survey. Feedback about CBE's survey format, speed of results delivery, and information provided by the online report was

overwhelmingly positive. We learned, for example, that individual comments were useful from the perspective of those directly managing the building, allowing management to formulate an action plan to address the issues raised (Zagreus and Huizenga 2003).

### Datamining

The next step is to implement exploratory data analysis tools so that comparisons can be made and trends explored in our growing database of standardized responses. Currently in development, a Java-based software application will enable users to dynamically explore the data in the survey database, in order to investigate hypotheses and observe relationships between IEQ satisfaction and various building technologies. The simple Web-based interface uses small multiples and other information visualization techniques to quickly lay out survey data in a cross-tab format, allowing survey results to be compared across two or more sets of buildings (Figure 5). A prototype of the tool was well received in usability evaluations, and development of the production version is underway (Zagreus and Hornung 2003).

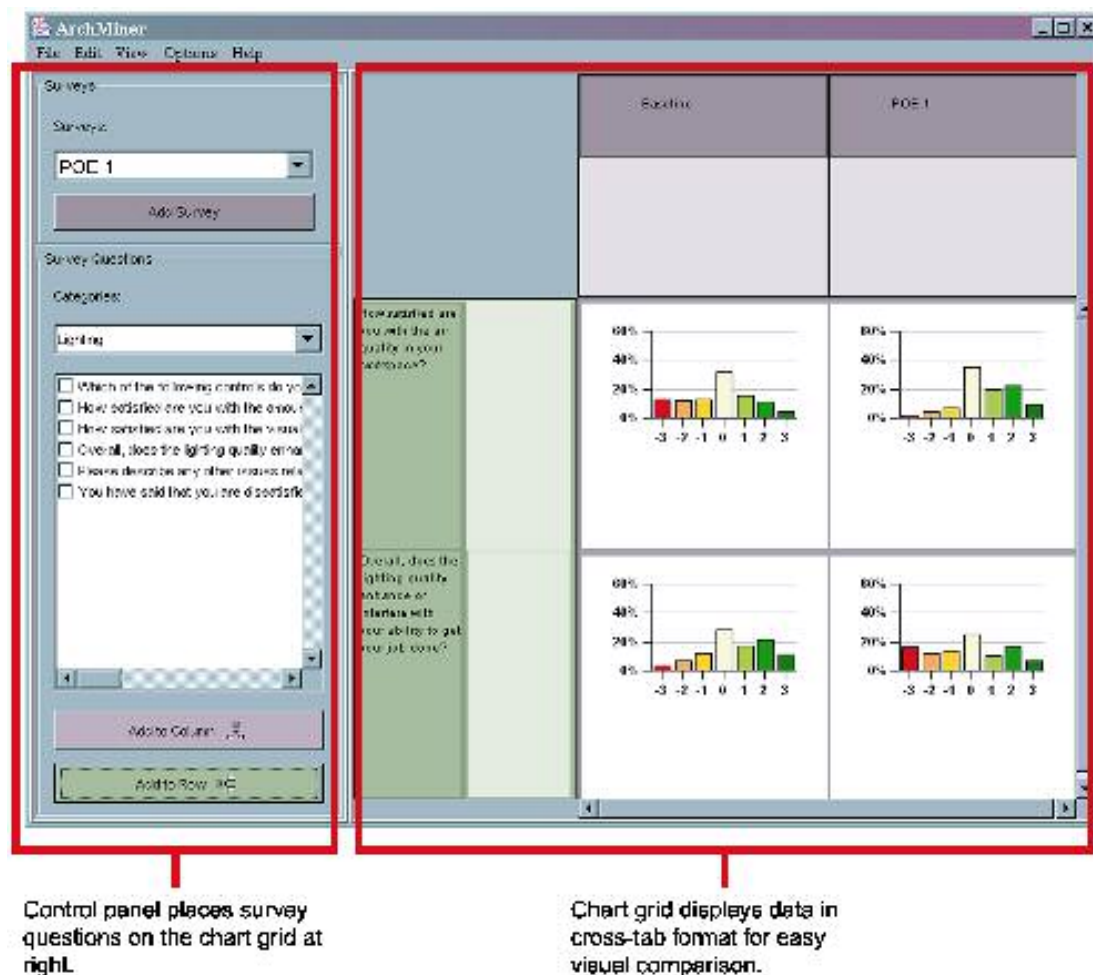


Figure 5. Screenshot of datamining tool.

## 5. CASE STUDIES

The survey has been used to evaluate the performance of more than 70 buildings in the United States, Canada and Europe, including office buildings, laboratories, banks

and courthouses. Survey clients include government and industry organizations, researchers, building operators, owners, architects and engineers.

Following we summarize two case studies. The first shows how survey results are currently being used to improve the indoor environment for occupants in a building, and may also, through educating the institutional clients, improve IEQ in their future building projects. In addition, it demonstrates the survey's use as a research tool, developing our knowledge of certain building technologies and how they affect occupant comfort. The last case study illustrates the use of survey data to benchmark building quality within a real estate portfolio.

**Case #1: Field Study – Large Office Building with Underfloor Air Distribution, Sacramento, California<sup>2</sup>**

This survey was used to conduct pre- and post-occupancy assessments of occupant comfort in a new building containing underfloor air distribution (UFAD) technology. UFAD systems are increasingly being used in the U.S., but very little whole-building performance data from completed projects has been collected. This project was designed to provide detailed data quantifying the relative impacts of UFAD technology on: energy use; IEQ; occupant satisfaction, comfort, and productivity; and first and life-cycle (operating) costs.

*Approach*

The research methodology includes occupant satisfaction surveys of the employees while in the old building using conventional overhead air distribution (“baseline”), as well as after relocating to the new space employing UFAD technology. The core occupant IEQ survey was used, along with a floor diffuser survey module developed for the study. To control for seasonal variation, the pre- and post-surveys were each conducted during the same time of year; the baseline survey was conducted during January 2002, and the survey in the new building took place almost exactly one year later. This was also timed to ensure that an acceptable interval elapsed between the relocation and the survey in the new building, in order to reduce any bias inherent in the disruption of the move or newness of the surroundings.

The entire population of the new building was invited to participate in the survey, and 47% did so, resulting in 516 valid responses. Of these, 334 occupants took the baseline survey as well. (The overall response rate for the baseline survey was 56%.) Responses for an individual from the two surveys were tracked together by means of a personal identification number entered by the respondent upon accessing the survey. The responses remain confidential and anonymous.

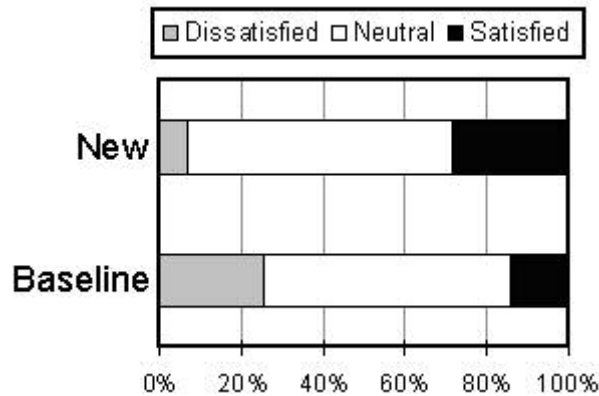
*Results*

The responses and comments from the two surveys were compared for all respondents who participated in both surveys. Among the findings, Figure 6 shows that air quality satisfaction improved significantly in the new building over the baseline. (As with the other results presented in this paper, this is significant at the 95% confidence level.) The increased satisfaction levels are likely due to the UFAD system, which delivers fresh supply air directly into the occupied zone via floor diffusers, and researchers

---

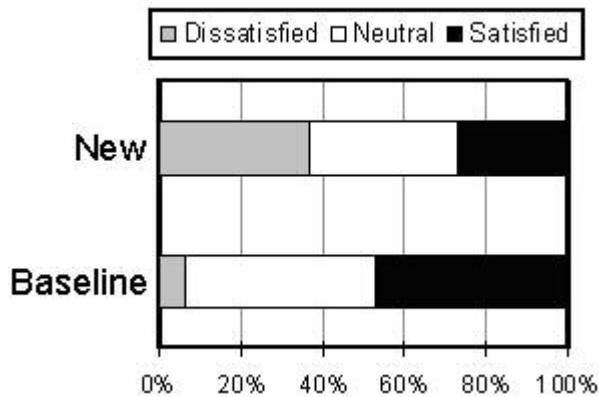
<sup>2</sup> This case study also appears in Zagreus et al (2004).

found that this was corroborated by a corresponding increase in air movement satisfaction levels in the thermal comfort category.



**Figure 6. Air quality satisfaction comparison of respondents who took both baseline and new building surveys (N=315).**

Not all categories showed improvement over baseline, however. Lighting satisfaction scores in the new building were significantly lower than baseline ratings (Figure 7). Survey comments indicated that much of the problem was due to the bulbs used in the task lighting, which provided a bright light that did not illuminate enough of the work surface. This information was passed on to building management and corrective actions are underway.



**Figure 7. Lighting level satisfaction comparison of respondents who took both baseline and new building surveys (N=314).**

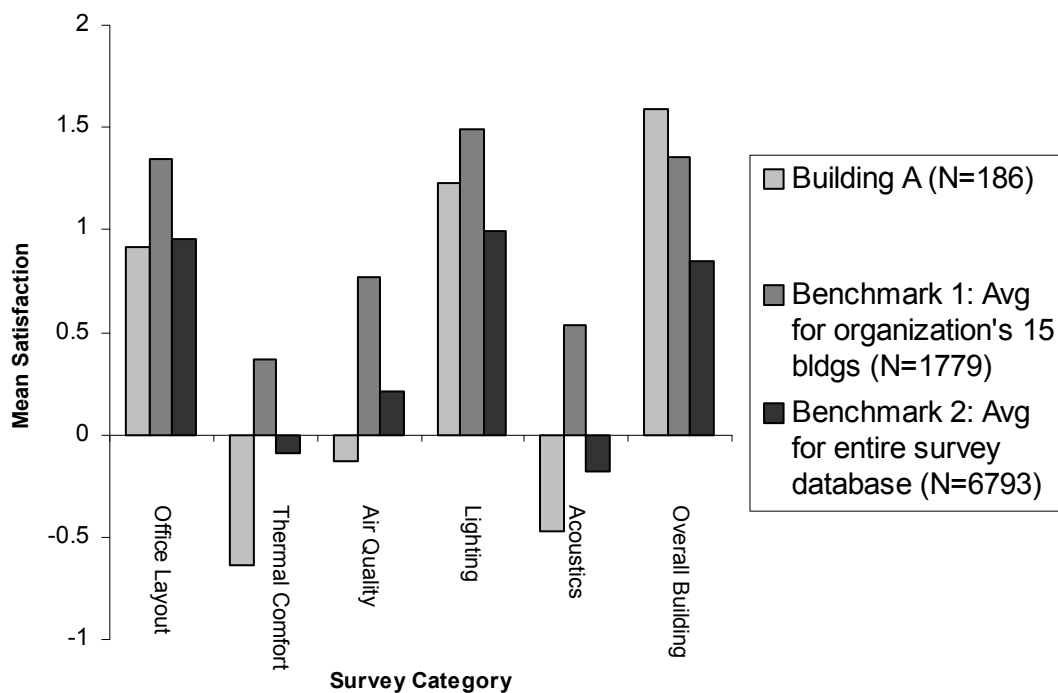
Responses to the floor diffuser module indicated that occupant education could have a significant impact on comfort. Most people did not have strong opinions about the location or number of diffusers, and most adjusted them infrequently. They were split evenly as to whether adjusting the devices improved their thermal comfort, yet even so, nearly 2/3 indicated a preference for UFAD over conventional overhead air distribution – a very encouraging result for the technology. It is likely that if building occupants received adequate training on the use of their floor diffusers, comfort would improve (Shirai 2003).

### *Discussion of preliminary findings*

This case study illustrates that using the survey can positively influence IEQ by several means. When conducted as part of a POE, the survey can have a direct effect on improving the comfort of occupants by ensuring that the building is performing as designed, and that the occupants benefit from the full potential of the building features. Results of this survey enable researchers and the building community to move forward in quantifying how UFAD technology compares with other HVAC systems, and it helps promote understanding of the installation, operation and maintenance of the technology among facilities staff. Another survey is scheduled to take place in the new building in February 2004 to determine how adjustments of the building systems have affected occupant comfort.

### **Case #2: Office Building Performance Comparison Study**

A large organization used the survey to elicit occupant feedback on how well its recently completed buildings meet the organization's design goals. To do this, they compared ("benchmarked") the performance levels of individual new buildings against the means and distributions of the overall stock of new buildings. The survey was administered six months or more after occupants had moved into each of the new buildings. Figure 8 shows results from one of these buildings compared side-by-side with the results for all 15 of the organization's new buildings, and against the entire survey database.



**Figure 8. Benchmark comparison of average satisfaction ratings by survey category.**

We can see that Building A is performing well below the mean score in nearly every category, particularly in thermal comfort, air quality and acoustics, suggesting that the HVAC system has significant design and/or operational deficiencies. Interestingly, although the facility is performing poorly compared to the benchmark categories, the overall building score is significantly higher than benchmark. A scan of the comments

reveals that occupants find the facility to be beautiful and well maintained, but want air quality problems to be resolved.

The chart also shows that the organization's set of new buildings (Benchmark 1) performs far better than the survey database as a whole (Benchmark 2). This indicates that the organization builds and maintains its facilities skillfully, though it should also be noted that newer buildings tend to get higher marks, and the survey database contains data for both old and new buildings.

## **6. CONCLUSION**

The CBE survey tools can be applied widely to evaluate the performance of individual buildings as well as to systematically compare the performance of groups of buildings. Useful feedback is provided to operations staff, supporting adjustments and improved IEQ for occupants of existing buildings. Survey results also inform the building community about the efficacy of various building technologies and design techniques. In addition, the survey is proving a useful resource for facility managers and building owners involved in acquiring, operating and improving their building portfolio.

Committed to overcoming the obstacles that prevent widespread use of POEs, CBE's goal is to create a feedback loop for building industry professionals, so that they can learn how various building design features and technologies affect occupant comfort, satisfaction and productivity. By creating this feedback loop, CBE hopes to help move the industry towards sustainable, healthy, comfortable workspaces.

## **7. REFERENCES**

Baughman, A, E Arens, F Bauman and C Huizenga (1995), Indoor Environmental Quality (IEQ) Assessment System: Development of IEQ Method and Field Demonstration at UC Davis Medical Center. Report to Johnson Controls, Inc., Center for Environmental Design Research, University of California, Berkeley, CA, USA, 150pp.

Brager, GS, G Paliaga and R de Dear (2004), Operable Windows, Personal Control & Occupant Comfort. Accepted for publication in ASHRAE Transactions, June.

Bordass W and A Leaman (2003), Beyond Probe: making feedback part of design? Presentation to CIBSE conference, Edinburgh, Scotland, 26 September 2003.

Center for the Built Environment (2004), Evaluating Perimeter Zone and Facade Performance. Retrieved from <http://www.cbe.berkeley.edu/RESEARCH/briefs-facades.htm>, 26 January 2004.

Eisenhower, D (2000), Documentation of the Results of the Cognitive Testing for the CBE Post Occupancy Evaluation Survey. Report to the Center for the Built Environment, Survey Research Center, University of California, Berkeley, CA, USA.

Federal Facilities Council (2001), Technical Report 145, Learning from our buildings: a state-of-the-practice summary of post-occupancy evaluation, National Academy Press, Washington, USA.



Heerwagen, JH (2001), A Balanced Scorecard Approach to Post-Occupancy Evaluation: Using the Tools of Business to Evaluate Facilities. In Federal Facilities Council, Technical Report 145: Learning from our buildings: a state-of-the-practice summary of post-occupancy evaluation (pp 79-87), National Academy Press, Washington, USA.

Kaplan, A (2001), The Role of Technology for Building Performance Assessments. In Federal Facilities Council, Technical Report 145: Learning from our buildings: a state-of-the-practice summary of post-occupancy evaluation (pp 42-53), National Academy Press, Washington, USA.

Leaman, A (2003), Post-occupancy Evaluation. Prepared for Gaia Research CPD Seminars on Sustainable Construction, January 2003.

Leaman, A and W Bordass (2000), Keeping Occupants "Satisfied". Energy and Environmental Management, Second Quarter, pp 23-27.

Leaman, A, W Bordass, R Cohen and M Standeven (1997), The Probe Occupant Surveys, Buildings in Use '97: how buildings really work. London Commonwealth Institute, London, UK.

Malin, N, J Boehland and K Johnson (2003), Post-Occupancy Evaluation: Learning from Experience with Green Buildings. Environmental Building News, September 2003.

Shirai, R, F Bauman and L Zagreus (2003), First Post-Occupancy Evaluation (POE) of Block 225: Capitol Area East End Complex. Interim Report to California State Department of General Services and California Energy Commission, Center for the Built Environment, University of California, Berkeley, CA, USA, August.

Usable Buildings Trust (2004), <http://www.usablebuildings.co.uk/WebGuideOSM/Wha17.html>. "What about questionnaires on the internet?"

Usable Buildings Trust (2004), What about questionnaires on the internet? Retrieved from <http://www.usablebuildings.co.uk/WebGuideOSM/Wha17.html>, 16 January 2004.

Zagreus, L and C Huizenga (2003), Using the CBE Occupant Survey To Assess Facility Management Performance in GSA Facilities, May 2003 Pilot Test. Summary Report to U.S. General Services Administration, Center for the Built Environment, University of California, Berkeley, CA, USA, August.

Zagreus, L and S Hornung (2003), ArchMiner Web site. Retrieved from <http://monkey.org/~dehfne/archminer/index.htm>, 26 January 2004.

Zagreus, L, C Huizenga, E Arens and D Lehrer (2004), Listening to the Occupants: A Web-based Indoor Environmental Quality Survey. Accepted for publication in Building Science: Papers from Indoor Air 2002 © 2004.

Zimring, C and T Rosenheck (2001), Post-Occupancy Evaluations and Organizational Learning. In Federal Facilities Council, Technical Report 145: Learning from our buildings: a state-of-the-practice summary of post-occupancy evaluation (pp 42-53), National Academy Press, Washington, USA.