Evaluation of Indoor Environment Quality with a Web-based Occupant Satisfaction Survey: a Case Study in Northern Italy

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SUMMARY
In this study the indoor environmental quality (IEQ) of an energy efficient 9400 m^2 Italian office building was investigated using an Italian-language version of the Center for the Built Environment's web-based survey. This survey allows the building's IEQ performance to be compared against a large database of previously surveyed buildings. In addition, it permits the specific causes of dissatisfaction to be identified. The study building was compared with 66 buildings having LEED certification. The analyzed building obtained scores higher than the median of the 66 LEED buildings in the categories: acoustic quality, thermal comfort, general satisfaction, air quality and office furnishings, and lower than the median in: cleanliness and maintenance, office layout and lighting. The subcategories: visual and acoustic privacy scored low. For these, layout and operational interventions were proposed. The building survey showed that high simulated energy efficiency and high measured IEQ can be accomplished simultaneously.

INTRODUCTION
Indoor Environmental Quality (IEQ) affects occupant health, wellness, comfort and productivity [1]. IEQ can be assessed by measuring the physical parameters that characterize IEQ and/or by asking to the occupants to assess their environments; occupants can be a rich source of information about IEQ.
ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), USGBC (United States Green Building Council) and CIBSE (Chartered Institution of Building Services Engineers) has been developing a document, entitled '*Performance Measurement Protocols for Commercial Buildings*', to provide a standardized and consistent protocol for measuring the energy, water, and IEQ performance of commercial buildings [2].
It proposes levels of intervention -low, medium and high- each with increasing cost and accuracy. These standardized methods provide realistic choices for consistent performance characterization of the building stock, and comparison to appropriate benchmarks [2]. An IEQ survey is the first, easiest and cheapest step to evaluate IEQ. The Center for the Built Environment (CBE) at the University of California Berkeley has developed such a survey and implemented it enough to have accumulated a large database for benchmarking. For a detailed description of CBE's survey tools, see references articles [3, 4]. The survey could be used to evaluate the effectiveness of building service providers, of a retrofit or of changes in building operations. The survey can be used to obtain LEED NC credit 7.2 or EBOM credit 2.1. In 2002 the Autonomous Province of South Tyrol (Italy) introduced a mandatory energy certification system for residential and commercial buildings, named CasaClima. The core of the certification is the classification of buildings according to their simulated space heat requirements; IEQ is not included in the certification process.

The purpose of this study is to use the survey to assess IEQ quality of an office building with an excellent energy rating as assessed by CasaClima, and to research the causes of IEQ dissatisfaction, if any.

METHODS

Survey

CBE's cost-effective web-based survey is used to evaluate the office layout, office furnishings, thermal comfort, indoor air quality, lighting, acoustics, building cleanliness and maintenance and the overall occupant satisfaction from the occupants' perspective. The survey is intuitive to use; it preserves respondents' confidentiality. Data access is controlled to maintain data integrity. A 7-point scale with endpoints "- 3 = very dissatisfied" and "+ 3 = very satisfied" as shown in Figure 1 is used to rate satisfaction and self-reported productivity.

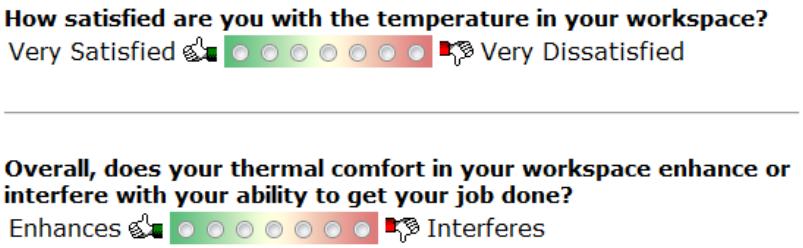

Figure 1. Example of CBE Survey questions.

Respondents who indicate dissatisfaction with an aspect of their work environment are presented with a follow-up page containing drill-down questions about potential sources of dissatisfaction, and a text box for written comments [3]. The approximate time required to complete the core survey is 5–12 min. Time to completion varies depending on the number of branching questions and comments answered [3]. The survey has been translated into eight languages, including Italian.

Building description

The CBE survey was implemented in a six-storey, 9400 m^2 office building in Bolzano (Italy). The building has been occupied since 2007; its envelope consists of glass and steel. With an estimated energy need of 25,4 kWh/(m^2year) the building is certificated "CasaClima A+", second-highest class in the CasaClima certification.

Description of the offices

There are offices on all floors of the building; private offices with glass partitions are the most common office typology. Private offices have different sizes: 4 x 3 m, 4 x 4 m, 4 x 5.5 m, 4 x 6 m and 5 x 7 m; depending on the size, offices contain one or more persons. The average U-value of the windows is 1.3 W/m^2K, and of the walls is 0.3 W/m^2K. The g-factor or solar heat gain coefficient of the glass partitions is 0.45. Window glass occupies about 70% of wall area. All the offices have operable windows, the majority towards the outdoor environment, the others toward the interior hall. External windows are equipped with manually controlled venetian blinds located between the windows' panes.

Description of the HVAC system

The building owner asked for an energy efficient HVAC system coupled with the use of renewable sources. The base energy demand for heating and cooling is covered with a ground

source heat pump. A condensing boiler fueled by natural gas is used for the winter peak load and for the hot water.
Ceiling radiant heating and cooling panels are used to condition offices and conference rooms, while the atrium and the common areas are heated and cooled by radiant floor panels. A mixing ventilation system is used for ventilation purposes and for the control of the relative humidity. The central air handling unit has a humidifier. The main stairwell, in the south side, is conditioned by the active radiant panel installed behind the slabs of the walls. Radiators are installed in the restrooms and in archives located in the underground floor. Part of the electricity is produced by the photovoltaic panels system installed on the roof.

RESULTS AND DISCUSSION

The survey was sent to 160 occupants; 81 people (51% of total) completed the questionnaire. Figure 2 shows the average scores of the analyzed building (mean value, represented with a blue diamond symbol) and of 66 LEED buildings form the CBE database; those data are reported with box-plots. The vertical line within the box is the median. The lines to the left and to the right of median represent the 25th and 75th percentiles, respectively. The vertical line joined to the box by the dashed line shows either the maximum or 1.5 times the interquartile range of the data, whichever is the smaller. Points beyond those lines are outliers. The interquartile range is the difference between the 25th and 75th percentiles.

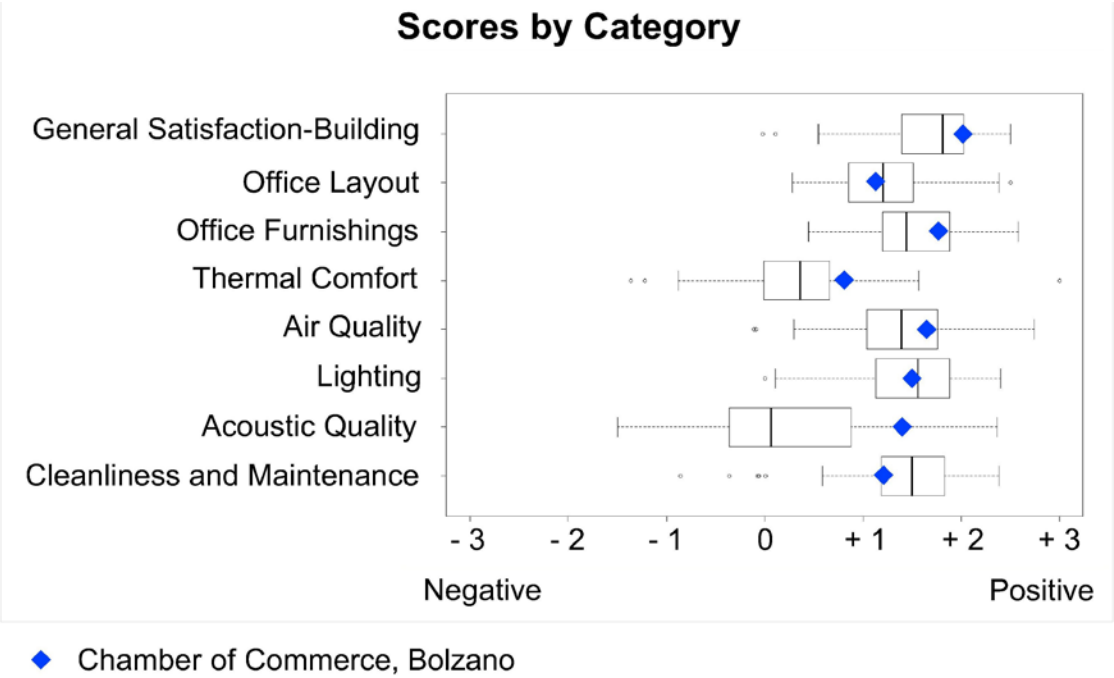

Figure 2. Scores in all categories.

The analyzed building (Chamber of Commerce of Bolzano) obtained scores higher than the median of the 66 LEED buildings in following categories: acoustic quality, thermal comfort, general satisfaction, air quality and office furnishings, and lower than the median in: cleanliness and maintenance, office layout and lighting. In acoustic quality and thermal comfort the analyzed building scored higher than the 75% of the 66 LEED buildings. Possible hypotheses for the high scores in acoustic quality are the good quality of the building envelope and the urban context. Aspects that may have contributed to obtain a high value in IAQ quality are the absence of pollutants and harmful materials (stone, metal, glass, and concrete are the main material used), the possibility of management of natural ventilation with windows and the age of the building: it was inaugurated in 2007.

To identify issues that need changes, the percentage of dissatisfied people were analyzed, in association with topics that obtained lower scores. These are thermal comfort and office layout. In the next part these are discussed and analyzed in order to propose interventions. Categories that obtained higher score are general satisfaction and office layout. Figure 3 report general satisfaction of the Chamber of Commerce of Bolzano; 93% of participants are satisfied with the buildings, 3% gave a negative score and 4% reported a neutral score. The studied building simultaneously achieved a high calculated energy saving and an elevated measured IEQ scores.

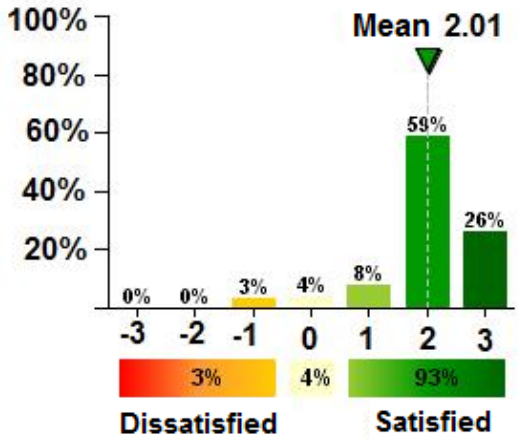

Figure 3. General satisfaction of the analyzed building.

The first part of the survey describes building occupants and their work. The results from questions relating to "background questions" are reported in Table 1. The percentage of men who participated in the survey is slightly higher than females (54%). The majority of respondents have worked in the building for one to two years. The type of work is primarily administrative, and is done for more than thirty hours per week.

Table 1. Background information (Number of participants: 78)

		Participants number	Participants percentage [%]
Gender	Female Male	36 42	46 54
Age	30 or under 31-50 Over 50	12 61 5	15 78 7
How many years have you worked in this building?	Less than 1 year 1-2 years 3-5 years More than 5 years	11 56 8 3	14 73 4 9
How long have you been working at your present workspace?	Less than 3 months 4-6 months 7-12 months More than 1 year	8 7 7 57	10 9 9 72
Type of work	Administrative support Technical, Professional Managerial/supervisory Other	51 11 7 9	65 14 9 12

Hours spent in the workspace	10 or less 11-30 More than 30	3 22 53	4 28 68

Table 2 reports the average score and the percentage satisfied and dissatisfied for each of the investigated categories. People that voted 1, 2 and 3 are classified as satisfied, those who voted -1, -2, and -3 are dissatisfied, the rest are classified as neutral. From the table it can be deduced that although there is some dissatisfaction, the building has a positive score in each category.

Table 2. Scores and percentage of satisfied and dissatisfied people.

	Mean scores (scale to -3 to +3)	Percentage of satisfied [1] [%]	Percentage of dissatisfied [1] [%]
General satisfaction	2.01	93	3
Office layout	1.15	71	21
Office furnishings	1.71	78	8
Thermal comfort	0.70	60	25
Air quality	1.64	83	5
Lighting	1.51	79	12
Acoustic quality	1.42	78	12
Cleanliness and maintenance	1.16	73	14

[1] Percentage of participants who answered the question.

Thermal comfort received the lowest average score, as shown in Table 2 (0.7 in scale from -3 to +3). Twenty-five percent of occupants report thermal discomfort.
CBE developed data mining software to analyze the survey results. Users can explore the survey database to discover causes for the results. The software was used first to identify the reasons for the thermal comfort dissatisfaction. In Table 3 the questions about satisfaction with the temperature and the influence of thermal comfort on the ability of performing the work are analyzed along with the gender and floor level variables.

Table 3. Thermal comfort: application of filters for the analysis of discomforts location.

Variable	Mean value of temperature satisfaction (scale to -3 to +3)	Enhances/ Interferes of ability to perform jobs (scale to -3 to +3)
Mean Vote (79 people)	0.70	0.94
Females Males	0.35 1.19	0.63 1.39
Ground floor 1st floor 2nd floor 3rd floor 4th floor and above	0.90 0.67 1.27 1.54 0.24	1.10 1.22 1.55 1.77 0.39

From Table 3 it can be deduced that: females expressed, on average, lower thermal comfort and self-reported productivity than males. Thermal comfort and productivity vary with the floor levels; this suggests that there are problems with the floor-to-floor regulation of the HVAC system. The analysis of additional thermal comfort survey questions showed that half

of the respondents reported that the discomfort happens in the morning and especially on Mondays (those values are not shown in the table). This may mean that the heating and cooling system is turned on too late in the morning, especially on Mondays after a weekend shutdown. Starting the HVAC system earlier may reduce complaints.

The data for the office layout and the acoustic quality categories was also examined in more detail. Table 4 summarizes the average scores and percentages dissatisfied, showing that visual and acoustic quality get low scores, 0 and 1.07 respectively. Twenty-one people said that people from outside can easily see inside the offices, because of their glass partitions. The acoustic privacy problem could be related to the types of partitions in offices and meeting rooms. From interviews performed after the survey it emerged that the meeting rooms, some with windows on all sides, have poor sound insulation, and people in the meeting rooms can hear speakers in adjacent rooms and vice versa.

Table 4. Scores and percentage of dissatisfied in office layout and acoustic quality.

	Scores (scale to -3 to +3)	Percentage of dissatisfied [%]
Satisfaction of available space	1.97	9
Satisfaction of visual privacy	0	39
Satisfaction of ease of interaction with colleagues	1.48	14
Enhances/ Interferes of ability to perform jobs	1.41	9
Satisfaction of acoustic quality	1.77	8
Satisfaction of acoustic privacy	1.07	17
Enhances/ Interferes of ability to perform jobs	1.35	15

To improve acoustic and visual privacy the following interventions to the building could be proposed: panelized sound insulation and satin film to reduce glass transparency, as shown in Figure 4 and Figure 5.

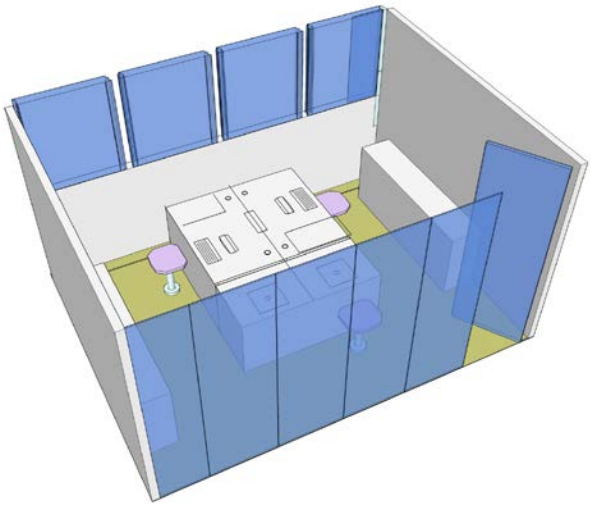

Figure 4. Example of office (4 x 3 m).

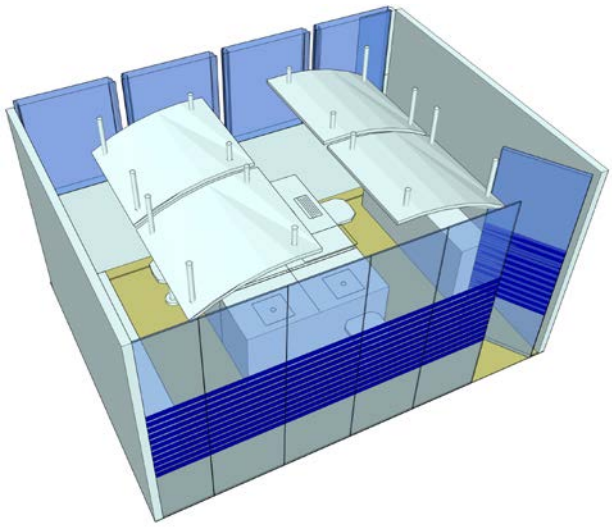

Figure 5. Systems to improve visual privacy and sound quality.

CONCLUSIONS

The studied building received a high indoor environmental quality score according to the CBE survey: 93% of respondents expressed satisfaction with the building.

The analyzed building obtained scores higher than the median of the 66 LEED buildings in following categories: acoustic quality, thermal comfort, general satisfaction, air quality and office furnishings, and lower than the median in: cleanliness and maintenance, office layout and lighting. In acoustic quality and thermal comfort the analyzed building scored higher than the 75% of the 66 LEED buildings.

Glass partitions between offices and corridors may be one of the possible causes of low perceived visual and acoustic privacy. Discomfort may be reduced through the application of satin films and sound-absorbing panels. Thermal comfort, which received the lowest score, could be increased through changes in operating hours HVAC system. The survey has proven to be a useful and inexpensive tool to investigate and identify the building's IEQ problems.

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