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Post-Occupancy Evaluation: An Inevitable Step Toward Sustainability

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Abstract

Post-occupancy evaluation (POE) is a platform for the systematic study of buildings once occupied, so that lessons may be learned that will improve their current conditions and guide the design of future buildings. Various aspects of the occupied buildings' functioning and performance can be assessed in a POE, both chemo-physical (indoor environment quality (IEQ), indoor air quality (IAQ) and thermal performance) as well as more subjective and interactional (space use, user satisfaction, etc.). POE draws on an extensive quantitative and qualitative toolkit: measurements and monitoring, on the one hand, and methods such as walk-throughs, observations and user satisfaction questionnaires on the other. POE may seem a necessary, indeed, axiomatic phase of the design and construction process, and exactly the kind of integrated assessment essential for the design of more sustainable buildings. Yet POE researchers have often been regarded with suspicion and even hostility, since their work may cause friction between different stakeholders. This chapter reviews material published in recent years in an attempt to trace the emergence of POE, describe its conceptual and methodological backdrop, its interaction with other issues related to sustainable design, and its increasing 'canonization' as a method. We argue that POE offers the potential to integrate a range of fragmented aspects of the construction process and of the relations of buildings to their environment and users. We propose that the acceptance of POE as a mandatory step in the design and commissioning of buildings, whose results are habitually fed backward and forward to other stages of the design and construction processes, is an important and probably inevitable step toward making buildings more sustainable.

■ *Keywords* – appropriate design; indoor air; indoor environment; monitoring; post-occupancy evaluation; survey; sustainability; thermal performance; user satisfaction; walk-through

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INTRODUCTION

BACKGROUND

Whereas designers expend considerable resources in examining the actual functioning of and user satisfaction with everyday commodities (especially successful ones), and in refining their design accordingly, this is not the case with buildings. Although they are disproportionately more expensive than cars, audio or electrical and electronic equipment, buildings are very rarely revisited and reassessed once they are handed over to their users. This lack of evaluation and study stems from numerous reasons and leads to a situation in which every single building remains a unique specimen, design mistakes are repeated, and when some re-evaluation of the building as an end product is undertaken, it is often based on non-systematic troubleshooting. In many cases it is hard to compare the results of such studies due to lack of uniform, standard procedures and protocols. It has been claimed that unless a systematic approach is taken for the benchmarking of buildings, improvement of current practices is left to a haphazard process that does not necessarily promote sustainability (Roaf et al, 2004).

The absence of regularized feedback from performance to planning and construction phases becomes ever more relevant under the current conditions which include (Meir, 2008):

- continuous rise in the consumption of energy, both per capita and in absolute terms;
- buildings in industrialized countries consume some 40–50 per cent of overall energy, from 'cradle-to-grave', but primarily during the operational part of their lives (heating, cooling, ventilation, lighting, etc.);
- the realization that fossil fuels are being depleted and that their use has adverse environmental, health, social, political and security implications;
- people in industrialized countries (but not only!) spending 80–90 per cent of their lives in buildings, living, studying, working, entertaining themselves, consuming and even exercising, which means that the indoor conditions can have a strong imprint on well-being, health and productivity (Pearson, 1989; Wargocki et al, 1999). The indoors is, in a very real sense, the human 'environment'.

At the same time as there are demands to decrease the use of energy, these coincide with increasing demand for comfort in buildings (Zeiler and Boxem, 2008; Zeiler et al, 2008). A pointed question that post-occupancy evaluation (POE) may answer is whether these increasingly stringent environmental constraints must come at the expense of occupant comfort and satisfaction. Or might achievements be made *simultaneously* in both dimensions, balancing energy consumption and occupants' demands for physical, physiological and psychological needs? It is difficult to answer these and similar questions without the kind of insights that POE offers into how buildings actually function and are perceived.

The tools employed in POE include plan analysis, monitoring of indoor environment quality (IEQ), indoor air quality (IAQ) and thermal performance, and surveys including walk-throughs, observations, user satisfaction questionnaires, and semi-structured and structured interviews. With some first attempts in the 1960s, POE was introduced in response to significant problems experienced in building performance with particular emphasis on the building occupant perspective (Preiser, 1995). POE serves as a way of providing subjective and objective feedback that can inform planning and practice throughout the building's life cycle from the initial design to occupation. The benefits from POE can be in the short, medium and long term:

- short-term benefits include obtaining users' feedback on problems in buildings and the identification of solutions;
- medium-term benefits include feed-forward of the positive and negative lessons learned into the next building cycle;
- long-term benefits aim at the creation of databases and the update, upgrade and generation of planning and design protocols and paradigms (Preiser and Vischer, 2005).

Despite these obvious benefits, POE researchers are often regarded with suspicion and even hostility, since their work may cause friction between different stakeholders (including architects, consultants, clients, owners, managers and users) and between these and the authorities (planning and health, for example), expose some of them to liability lawsuits, and others to potential demand for upgrade investments. This institutional and professional fragmentation of authorities, perspectives and liabilities has hampered the uptake of POE as a self-evident part of the design and construction professions and industry.

This chapter attempts to outline the various issues related to POE, draw a picture of the current state of affairs and suggest some possible steps for the canonization of POE within the planning, design and construction domains. Various sources were reviewed in order to assess the evolution and state of the art of this field, among them peer-reviewed journals, electronic databases (Science Direct, Scirus, Web of Science, Google Scholar) and conference proceedings (including *Windsor 2004 Conference – Closing the Loop*; *Indoor Air* 2002, 2005 and 2008; *Healthy Buildings* 2003 and 2006; *Passive Low Energy Architecture (PLEA)* 1988–2008; and *Passive Low Energy Cooling (PALENC)* 2005 and 2007). In addition, curricula of selected schools of architecture were searched online for POE-oriented courses and programmes with a POE emphasis.

More than 100 papers from these sources were selected for more in-depth examination and categorized according to types of projects (residential, educational, public and institutional buildings, research facilities, clusters), aims and targets (energy consumption, IAQ, IEQ, user satisfaction) and tools and methods employed (walk-through, monitoring, questionnaires, surveys). The results have been compiled in Table 7.1, which may be used as a synoptic overview of the paper's bibliographic sources.

It is important to note that despite the wish to gain a full understanding of projects, particularly buildings, and the interaction of these and their systems with the building users, the parameters involved are numerous, the interrelations complicated and often not straightforward, and the resources needed for conducting a full POE are often beyond the reach of entrepreneur, designer, owner or user.

POE may be divided into two broad types: lateral studies investigating a limited number of parameters in a large number of case studies; and in-depth studies providing

TABLE 7.1 Synoptic overview of POE studies in selected papers

REFERENCE	TITLE	BUILDING TYPE	DIMENSIONS EVALUATED	METHODOLOGIES	SCOPE
Abbaszadeh et al (2006)	Occupant satisfaction with indoor quality in green buildings	Office	Pathogens, allergens Indoor environmental quality: thermal comfort, air quality, lighting, acoustics	Web-based IEQ survey	181 office buildings
Baird and Jackson (2004)	Probe-style questionnaire surveys of building users – an international comparison of their application to large-scale passive and mixed-mode teaching and research facilities	Academic, educational, office	Users satisfaction, use of space, thermal control	Public access to POE/PROBE surveys	3–5 days, 5 buildings (complexes) 1241 respondents
Bordass and Leaman (2004)	Probe: how it happened, what it found and did it get us anywhere?	Clinics, hospitals, offices, residential	Occupant control of systems and windows, maintenance	Review of published research, questionnaires	
Buhagiar (2004)	A post-occupancy evaluation of manipulating historic built form to increase the potential of thermal mass in achieving thermal comfort in heavyweight buildings in a Mediterranean climate	Historic buildings	Thermal comfort, occupants' satisfaction	Questionnaires survey, structured interviews	4 historic buildings
CABE (2006)	Assessing secondary school design quality	Secondary schools	Building functionality (access, space and uses), built quality (performance, engineering and construction), and impact (sense of place and effect on community)	Photographic walk-through, database, evaluations written by design and construction professionals trained as CABE enablers, client interviews, follow-up, web surveys of enablers for overall recommendations	2000–2005, 52 schools

CABE (2007)	A sense of place – what residents think of their homes	Residential	User satisfaction	Survey into the views of 643 residents living in 33 developments. In addition, 704 residents took part in census surveys at six case study developments	2006
Coulter et al (2008)	Measured public benefits from energy efficient homes	Residential house	Energy efficiency, owner satisfaction	Monitoring and questionnaires	7141 residential houses
Daioumaru et al (2008)	Thermal performance evaluations of DSF with vertical blinds	Public building	Thermal comfort	monitoring	
Davara et al (2006)	Architectural design and IEQ in an office complex	Public building, offices, multifunctional	IEQ, space usability, air temperature, relative humidity, light intensity, CO_2	Walk-through, interviews, spot measurements, short-term monitoring	1 multifunctional facilty
Donnell-Kay Foundation, Denver, CO (2005)	School facility assessments: State of Colorado	School	Assessments of physical condition, educational suitability, technology readiness, site condition and capacity/utilization	BASIS® School facility assessment system	2004, 7 Colorado districts, 22 schools
Etzion (1994)	A bioclimatic approach to desert architecture	Residential	Indoor temperatures, thermal performance	Monitoring	1 single family detached house
Etzion et al (1993)	Project monitoring in the Negev and the Arava, Israel	Residential, office, educational	Indoor temperatures, thermal performance	Monitoring	Student accommodation, 1 multifunctional educational building

TABLE 7.1 Synoptic overview of POE studies in selected papers (*Cont'd*)

REFERENCE	TITLE	BUILDING TYPE	DIMENSIONS EVALUATED	METHODOLOGIES	SCOPE
Etzion et al (2000a)	A GIS framework for studying post-occupancy climate-related changes in residential neighbourhoods	Residential, clusters	Climate-related building changes	Survey, walk-through, GIS	Residential neighbourhoods
Etzion et al (2000b)	Climate-related changes in residential neighbourhoods: analysis in a GIS framework	Residential, clusters	Climate-related building changes	Survey, walk-through, GIS	Residential neighbourhoods
Etzion et al (2001)	An open GIS framework for recording and analyzing post-occupancy changes in residential buildings – a climate-related case study	Residential, clusters	Climate-related building changes	Survey, walk-through, GIS	Residential neighbourhoods
Frenkel et al (2006)	POE of a scientists' village complex in the desert – towards a comprehensive methodology	Educational complex	Energy consumption, IEQ	Short-time monitoring, observations, questionnaire surveys	Educational complex: office building, dorms, classrooms, facilities
Genjo and Hasegawa (2006)	Questionnaire survey on indoor climate and energy consumption for residential buildings related with lifestyle in cold climate areas of Japan	Residential	Thermal comfort, energy consumption	Questionnaire	
Hydes et al (2004)	Understanding our green buildings: seven post-occupancy evaluations in British Columbia	Academic, educational, office, industrial	User satisfaction, use of space, thermal comfort	Not noted	Not noted

Ito et al (2008)	Field survey of visual comfort and energy efficiency in various office buildings utilizing daylight	Office	Daylighting	Questionnaire, measurements	9 office buildings, 2002–2007
Kenda (2006)	Pneumatology in architecture: the ideal villa	Residential, clinic	User satisfaction, ventilation		
Kosonen et al (2008)	Perceived IEQ conditions: why the actual percentage of dissatisfied persons is higher than standards indicate?	Office	User satisfaction	A web-based IEQ survey	29 office buildings
Kowaltowski et al (2004)	From post occupancy to design evaluation: site planning guidelines for low income housing	Residential, public space	User satisfaction, use of space thermal control	Questionnaires of selected representative public	107 questionnaires were applied in five housing areas during a period of 4 months at the end of 2003
Langstone et al (2008)	Perceived conditions of workers in different organizational settings	Educational, office, commercial	User satisfaction, use of workspace in addition to thermal, visual, acoustic comfort	Questionnaires	2 years, 14 case studies, 555–4500 respondents
Leaman and Bordass (1999)	Productivity in buildings: the “killer” variables	Office	User satisfaction, use of workspace		
Levin (2005)	Integrating indoor air and design for sustainability	All	Material use in green building thermal performance, POE		
Lighthall et al (2006)	Renovation impact on student success	School	Impact of large scale renovations of school buildings on facilities, student achievement, attendance and suspension rates, as well as	Data were collected and analyzed from end-of-grade and end-of-course exams,	2005, 18 schools

TABLE 7.1 Synoptic overview of POE studies in selected papers (*Cont'd*)

REFERENCE	TITLE	BUILDING TYPE	DIMENSIONS EVALUATED	METHODOLOGIES	SCOPE
			the impact on stakeholder satisfaction	SAT scores, average daily attendance, out-of-school suspensions and parent satisfaction surveys. Interviews were also conducted with school staff regarding their satisfaction during and following renovations	
Loftness et al (2006)	Sustainability and health are integral goals for the built environment	Offices, schools, hospitals	User satisfaction, worker productivity as function of all aspects of health and well being in built environment, SBS, energy consumption/conservation, VOC, TVOC, visual comfort, thermal comfort, ventilation, pathogens, allergens	Review of published research, correlation of results	1995–2005
Mahdavi et al (2008)	Occupants' evaluation of indoor climate and environment control systems in office buildings	Office	IEQ, occupants' control	Interviews, long-term measurements	5 buildings, 68 respondents
Marmont (2004)	City Hall London: evaluating an icon	Office	User satisfaction, use of space	Evaluation of data	
McMullen (2007)	Determining best practices for design, implementation and service	University library	User satisfaction	Photographic walk-through, client interviews, professional analysis	2007, 19 interviewees

Meir (1990)	Monitoring two kibbutz houses in the Negev desert	Residential	Indoor/outdoor temperatures	Monitoring	Symmetrical building discrepancies evaluation
Meir (1998)	Bioclimatic desert house – a critical view	Residential	Indoor climate, thermal comfort, energy consumption, water consumption	Monitoring	1 single family detached house
Meir (2000a)	Integrative approach to the design of sustainable desert architecture: a case study	Residential	Temperature, relative humidity, thermal comfort, water consumption, landscaping	Monitoring	Single family detached house
Meir (2000b)	Courtyard microclimate: a hot arid region case study	Courtyard of health facility	Outdoor air temperature	Short-term monitoring	Courtyard microclimate variability
Meir and Hare (2004)	Where did we go wrong? POE of some bioclimatic projects, Israel	Schools, visitor centre, residential, landscape	Occupant control of systems and windows, maintenance, training of occupants	Walk-through, interviews	Single buildings
Meir et al (1995)	On the microclimatic behaviour of two semi-enclosed attached courtyards in a hot dry region	Residential courtyards	Temperatures, shading simulations	Monitoring, CAD shading simulation/ visualization	Comparative behaviour of courtyards with different orientation
Meir et al (2007)	Towards a comprehensive methodology for post-occupancy evaluation (POE): a hot dry climate case study	Dormitory	User satisfaction, thermal control	Walk-through, survey, questionnaires	1–2 weeks for each building during winter and summer, 2 dormitories, 31 tenants

TABLE 7.1 Synoptic overview of POE studies in selected papers (*Cont'd*)

REFERENCE	TITLE	BUILDING TYPE	DIMENSIONS EVALUATED	METHODOLOGIES	SCOPE
Menzies and Wherrette (2005)	Windows in the workplace: examining issues of environmental sustainability and occupant comfort in the selection of multi-glazed windows	Office	Window controllability, lighting user satisfaction, environmental sustainability, productivity	Monitoring, questionnaires	4 office buildings
Mochizuki et al (2006)	Field measurement of visual environment in office building daylight from lightwell in Japan	Office	Daylighting, energy consumption, visual comfort	Questionnaires, measurements	
Morhayim and Meir (2008)	Survey of an office and laboratory university building – an unhealthy building case study	Multifunctional, educational, university, office	IEQ, usability, user satisfaction	Walk-through, surveys, questionnaires, interviews, measurements	Comprehensive analysis of one university building
Nakamura et al (2008)	The evaluation of productivity and energy consumption in 28 degrees office with several cooling methods for workers	Office	Energy consumption, thermal environment, performance, productivity	Simulation, evaluation	
Nordberg (2008)	Thermal comfort and indoor air quality when building low-energy houses	Residential house	Thermal comfort	Short- and long-term measurements	1 house, includes 3 units, without conventional heating systems
Patricio et al (2006)	Double-skin facades: acoustic, visual and thermal comfort indoors	Commercial and services building employed the DSF technology	Energy consumption, visual, acoustic and thermal comfort	Monitoring	
Pearlmutter and Meir (1995)	Assessing the climatic implications of lightweight housing in a peripheral arid region	Residential	Indoor temperatures, relative humidity, MRT	Monitoring	Heavy vs light construction

Pearlmuuter and Meir (1998)	Lightweight housing in the arid periphery: implications for thermal comfort and energy use	Residential	Temperature, relative humidity, MRT, energy consumption	Summer/winter-monitoring, various operation modes, thermal simulation	1 heavy-, 2 lightweight housing units
Pearlmutter et al (1996)	Refining the use of evaporation in an experimental down-draft cool tower	Multifunctional, educational	Evaporative cooling potential, indoor temperature and relative humidity	Monitoring	Cooling potential, alternative evaporative cooling technologies
Pfafferott et al (2004)	Comparison of low-energy office buildings in summer using different thermal comfort criteria	Office	Thermal comfort	Monitoring	12 office buildings with passive cooling systems
Pitts and Douvlou-Beggiora (2004)	Post-occupancy analysis of comfort in glazed atrium spaces	Educational building	Thermal comfort	Measurements	Summer and winter, 300 respondents
Preiser (2004)	Evaluating Peter Eisenman's Aronoff Center: De-Bunked De-Constructivism	Academic, office, studio, hall	User satisfaction, use of space	Evaluation of data	
Roaf (2004)	Cave Canem: will the EU Building Directive bite?		Use of space		
Sanoff (2004)	Schools designed with community participation	Schools	User satisfaction	Walk-through and surveys by clients (teachers) POE in conjunction with design process	2000, 50 teachers participated

TABLE 7.1 Synoptic overview of POE studies in selected papers (*Cont'd*)

REFERENCE	TITLE	BUILDING TYPE	DIMENSIONS EVALUATED	METHODOLOGIES	SCOPE
Silva et al (2006)	Monitoring of a double skin façade building: methodology and office thermal and energy performance	Commercial and services building employing the DSF technology	Energy consumption, visual, acoustic and thermal comfort	Short-term monitoring	
Stevenson (2004)	Post occupancy – squaring the circle: a case study on innovative social housing in Aberdeenshire, Scotland	Residential	User satisfaction, use of space, thermal control, energy consumption	Tenant interviews, energy use data	2 weeks, evaluations of all 14 houses in project, surveys and interviews, 2002 and follow up in 2004
Vainer and Meir (2005)	Architects, clients and bioclimatic design: a solar neighbourhood POE	Residential neighbourhood, houses	User satisfaction, building performance, energy consumption	Plan analysis, questionnaires, structured interviews, walk-through and visual analysis	79 single-family detached houses, solar neighbourhood
Wagner et al (2007)	Thermal comfort and workplace occupant satisfaction – results of field studies in German low energy office buildings	Office	User satisfaction, use of workspace	Field study and questionnaires	2004, 1300 questionnaires in 16 low energy German office buildings, summer and winter
Watson (2003)	Review of building quality using post-occupancy evaluation	School, dormitory	User satisfaction	Walk-through and surveys by POE interviewers	3 projects

Watson (2005)	Post-occupancy evaluation – Braes high school, Falkirk	School	User satisfaction	Walk-through and surveys by clients	2000, 55 stakeholders incl. pupils, staff and other school users, as well as council officials and technical staff involved in the design, construction and maintenance of the building
Woollett and Ford (2004)	How happy are we? Our experience of conducting an occupancy survey	Office	User satisfaction, use of space, thermal control	Written survey	4 hour, one time sample, 48 respondents
Xiong (2007)	The impact of exterior environmental comfort on residential behaviour from the insight of building energy conservation: a case study on Lower Ngau Tau Kok estate in Hong Kong	Residential	User satisfaction, thermal control	Interviews, measurements, simulations	One month (Aug), 40 sampling sites
Zagreus et al (2004)	Listening to the occupants: a web-based indoor environmental quality survey	Office	To introduce a-web based survey and accompanying online reporting tool	A web-base IEQ survey	3 case studies of office buildings

a detailed analysis of all possible parameters in a single case study. Several lateral studies were reviewed for this chapter, among them the European research project HOPE which surveyed 97 apartment buildings and 67 office buildings (Roulet et al, 2005, 2006), the Probe project (Bordass and Leaman, 2004) covering more than 20 office and public buildings in the UK, a study of office and institutional buildings in the US (Zagreus et al, 2004) and smaller studies such as those by Mahdavi and Proeglhoef (2008) on user control actions in office buildings in Austria. An example of an in-depth case study is recorded by Morhayim and Meir (2008) in which a university building including offices, laboratories and assorted facilities was investigated using observations and walk-throughs, monitoring, questionnaires and plan analysis.

Our goal in this chapter is not an exhaustive review of all material published on POE, but, rather, to trace current practices and methods, lacunae and problems, and point to potential modifications and protocols.

AIMS AND TARGETS OF POE

The nature and goals of POE depend on who is asked, as the prospects and hazards of this tool and approach are seen differently from the standpoint of each stakeholder.

The *entrepreneur* should have a vested interest in POE as a way to assess the design quality and potential gains – value for money invested – enabled by a better end product, i.e. the building. Against such potential gains, however, entrepreneurs do not always want too probing a light to be thrown on the performance of their buildings and, in extreme cases, they will be wary of their legal liability for malfunctioning or hazardous buildings.

The *building manager* should be interested in lowering energy consumption and maintenance costs, and an understanding of the actual operation of the building by the users is an essential step towards this. It has been demonstrated that often there is an acute discrepancy between objective comfort (such as thermal comfort defined by ASHRAE (1992)) and subjective comfort (such as defined by the adaptive thermal model (Nicol and Humphreys, 2002)). Studies have demonstrated energy waste alongside thermally uncomfortable interiors (overheated or overcooled), as well as increased energy consumption in buildings in which there is no control over one's personal space (air temperature, light intensity, etc.).

The *building user*. Here we can distinguish between the emphasis on well-being and health (in the case of the building's occupants, workers, tenants, students, etc.) and an emphasis on productivity (in the case of the company owner/manager of the building or the institutional entity responsible for it (the education system, etc.). These two emphases are clearly intertwined, although in reality clashes of interest exist (Davara et al, 2006).

The *architect* and *consultants* should be aiming at producing the best possible building within the existing economic, statutory, technical and other constraints. The responsibility of design professionals for the well-being of the people that occupy their buildings is an obvious but sometimes overlooked basic principle, sometimes inscribed in professional ethics codes and legislation. As an example, the second paragraph of the *Israeli Bylaws of Engineers and Architects* states that the first and foremost task of the architect and the engineer is to ensure public health and safety (IAUA, 1994), issues definitely associated with IAQ and IEQ. This often causes raised eyebrows among architecture students, as these mundane duties do not square with their initial glamorous image of the design professions!

Institutional stakeholders, i.e. the various governmental bodies concerned, on the national and political levels should be interested in the promotion of better design and building practices, such as would be enabled by a continuous process of assessment and upgrade that can be facilitated by POE. In severe cases, faulty buildings characterized by sick building syndrome (SBS) cause absenteeism, hospitalization and may create demands for potential compensation for long-term health and other damages. Institutional stakeholders will also be motivated to achieve the added longevity of better buildings and systems, minimizing the need for changes, refurbishment or demolition and reconstruction.

While each of these stakeholders approaches POE from differing and at times conflicting viewpoints, it is clear that all have much to gain from a thoroughgoing institutionalization of POE practices and from the extensive use of these methods for understanding flaws in current practices and producing solutions for the correction of these.

TOOLS AND METHODS USED IN POE

Since buildings are very complex systems, and their interaction with occupants further compounds the complexity of possible interrelations and potential malfunctions, it is imperative that the study of building post occupancy be based on a multi-level, multi-faceted system of checks and tests. These should involve thermal comfort alongside heating, ventilation and air-conditioning; illumination and visual comfort; occupants' satisfaction and behaviour; and, not least, physiological and psychological comfort, since all of these issues together will affect energy consumption and human well-being.

The methods and tools employed are both quantitative and qualitative, and may be classified in three rough categories on the basis of the information analysed and assessed.

Measurements, monitoring, sampling

Some key parameters that may be measured include temperature, relative humidity, air movement, light intensity, noise levels, pollutants, allergens and pathogens, volatile organic compounds (VOC) of various compositions and forms (e.g. formaldehyde) and their overall combination expressed as total volatile organic compounds (TVOC), gases of different types (CO, CO_2), electromagnetic fields and radiation (including radon), etc. While these may seem the most concrete and unequivocal aspects of a building – simple to measure and straightforwardly comparable with established objective standards – POE has shown that the picture is somewhat more complex than may be suggested by a traditional building physics approach (Pati and Augenbroe, 2006).

For example, while national and international standards exist for some of these parameters, recent research has questioned the validity of some of these, for example, the thermal comfort standards defined by ASHRAE *Standard 55* (2004). This is rigid in its upper and lower thresholds, yet its opening statement defining thermal comfort as 'the state of mind that expresses satisfaction with the surrounding environment' suggests that things may not be so clear cut. An alternative adaptive model advocated by Nicol and Humphreys (2002) assumes behavioural and cultural differences, as well as varying degrees of readiness to accept environmental conditions beyond these rigid thresholds. Thus, it may not be enough to measure the physical factors in a given environment, nor, indeed, to measure thermal parameters in isolation, since accumulating evidence indicates a significant degree of influence of psychological factors on the physiology of subjects (Mallick, 1996; Faruqui Ali et al, 1998) and the interaction of other attributes (such as noise) with thermal comfort levels (Pati and Augenbroe, 2006). These effects bring thermal comfort out of what has been assumed in recent decades to be the task of HVAC engineers.

Similarly, while visual comfort is addressed by different standards based on light intensity measurements in isolation, individuals relate differently to both the quantitative properties and non-quantitative qualities of light in different settings. Thus, whereas CIBSE *Code for Interior Lighting* (CIBSE, 1994) provides quantitative standards for different tasks, it says little on qualitative issues such as material properties like texture and colour which may influence visual requirements and comfort. Such complex interactions come into play when combining natural and artificial lighting, which has the potential to promote energy conservation, but also poses special challenges and problems for measurement and standard setting. This, together with the limited research on daylighting utilization possibilities in specific climatic regions (e.g. with high solar radiation throughout the year), limits the flexibility and options of designers and creates a dependence on electric lighting for performing visual tasks (Ochoa and Capeluto, 2006). With these limitations on the uses of theory and standards for designing for visual comfort, the emphasis on the kind of empirical measurements and feedback offered by POE becomes all the more important. POE, thus, becomes a bridge not only between pre- and post-occupation phases, but also between objective and subjective in the responses of people to buildings and between various domains of experience which interact in shaping overall satisfaction.

In addition to the complexities inherent in the subjective and interactional nature of temperature or lighting parameters, additional complexities may arise in the sampling procedures and the level of the standard themselves. Sampling and monitoring of various compounds differ from one country to another and even where such standards do exist, they are often relative and not absolute. For example, the maximum acceptable concentration of CO_2 is defined by ASHRAE *Standard 62* (1992) as up to 700 ppm *above* the outdoor levels, and radiation is often assessed in relation to *background levels*. Other compounds of biological significance are often not considered, and rarely sampled.

Compared with the above, energy consumption would seem a relatively easily quantifiable parameter, since it is already measured continuously at the electricity supply. However, more refined analysis of this parameter can provide useful insights into a building's qualities, properties and problems, such as the comparison of such basic measurements with a base case or a standard such as the PassivHaus (2008), which defines targets for energy consumption per floor area.

Finally, additional discrepancies or inaccuracies may arise related to the minimum accuracy desired, calibration procedures, minimum monitoring period and/or number of samples, which must be specified to avoid undue variance in the data or misleading results. Attempts to standardize such procedures and protocols do exist (see, for example, Spengler et al, 2000), but these can be compromised by different considerations and limitations, not least by actual on-site capacity, local and national differences, etc.

Surveys, questionnaires, cohort studies, observations, task performance tests

Such tools may be used by themselves or, preferably, in combination with the more quantitative measurements described above. While some may consider the type of tools drawn from the psychological or social sciences to be supplementary, and of use primarily to gauge user satisfaction, there are researchers who consider them no less accurate and representative than physical measurements and monitoring, so that a cleverly prepared questionnaire may provide as much as 80 per cent of all needed indicators for the assessment of building performance.

The main purpose of these tools is to help understand the intricate interrelations between a building, its users and the various systems that are part of the building's operation. Whereas measuring air temperature within a space seems to be rather straightforward, how this temperature is perceived by the individual is a totally different issue, often affected by parameters other than physiology or temperature *per se*. Such questionnaires are used to quantify the subjective perception of indoor parameters by asking interviewees to rank temperature, light, noise, ventilation, overall satisfaction and other parameters on five- or seven-degree scales. Questionnaires may be in hard copy or online, filled in by interviewee or surveyors.

Task performance tests are used in order to understand the influence of indoor parameters on the ability of the user to perform satisfactorily over a given period of time whether short or long term. This may be of importance both in terms of subjective well-being and objectively measured productivity. Such tests usually involve a repetition of a series of tasks such as word identification, form matching, typing, simple or complex mathematical calculations or other activities similar to those that users are typically expected to perform. Non-optimal indoor conditions – hotter or colder than neutral, flickering light or light levels that are too high or too low, lack of fresh air supply, noisy environments, smells, etc. – will eventually affect the outcome of the test, showing a decline in performance capabilities (Amai et al, 2007).

While theoretically dealing with the subjective perception of indoor conditions, and individual interventions, taken collectively, such assessments also offer a good overall indication of the indoor environment's condition and properties.

Document analysis, on-site observations

Document analysis can be divided into two main groups. In the pre-construction stage, drawings, briefs and specifications can be critically analysed to allow correction of potential mistakes. These may range from architectural details such as oblique angles of walls and structural elements causing not only usable space loss (Marmont, 2004) but also being the cause of behavioural problems within the spaces (Preiser, 2004).

Surveys and stationary and walk-through observations are also used to identify various building or building system problems, among them the actual use of spaces and details (such as user-devised *ad hoc* shading solutions common in fully glazed facade buildings, open windows in conditioned buildings indicating indoor conditions outside the comfort zone or lack of sufficient outdoor air supply) or other indicators such as mould and stains on HVAC outlets, walls and ceiling indicating potential health hazards.

DISCUSSION

Having briefly reviewed POE from the standpoints of various stakeholders in buildings, and some of its methods and goals, we can reflect on how POE can play a role in mediating and bridging some key tensions in contemporary building design.

POE IN THE BALANCE OF CREATIVITY AND UTILITY IN BUILDING DESIGN

For example, POE can inform the debate regarding the trade-offs of creativity and utility in buildings. In the modern age, the former has found more widespread expression as monumental buildings are designed not only to house religious or public institutions: spectacular museums, libraries and universities are joined today by apartment blocks and offices as landmarks. Everyman and company can commission a building that says 'art', not just architecture. Today's new tools allow architectural forms to be constructed within a spectacularly wide design scale. Buildings with non-repeating unique structural components are now commonly engineered and constructed. How do these capabilities interact with the familiar constraints of cost, and the forward-looking constraints of energy efficiency?

The contention is that the market is full of spectacular and unique buildings that may be jewels to view but are unethical in the use of energy, land and budget. Even those that gesture to sustainability may fall short: their rugs may meet the highest standards of recycled content, the paints free of VOCs and the high-performance windows the most insulated available; at the same time, however, they may have unwarranted use of some of these components in the building, in particular if the building has a curious shape. In other words, even though the building may use more efficient materials, it may use more of them, or, more of another kind of less efficient material. For example, in the case of wrap-around glazing, true energy savings could be attained with fewer windows altogether.

POE can play a role in attempts to determine an acceptable balance between creativity and utility. It does this by bringing in the element of user satisfaction as well as the actual functioning of the building, which together constitute its utility, and can help assess if and how the more imaginative or artistic elements interact with these. Currently, POE of 'green' buildings assumes that they are utilitarian in design and, therefore, measuring satisfaction of the air quality, lighting, thermal conditions, energy use and perhaps workspace comfort is sufficient. Roaf (2004) is critical of the current definitions of 'green' and 'sustainable' for all projects (that is, the idea that all projects today need to be sustainable) and in particular when confronted with 'signature buildings' that may be green in material selection and thermal standards of each element, but lack sense when it comes to total material use, use (read 'waste') of space in work areas and in public access zones of these buildings (Wilson and Austin, 2004). Roaf (2004) contends that POE needs to be expanded to contend with design and layout parameters in addition to the ones covered in research and surveys to date.

POE IN EDUCATIONAL BUILDINGS

Perhaps one of the areas in which POE has a most compelling role, and is also most likely to make inroads in institutional terms, is in the design and construction of schools. As opposed to private and corporate construction processes, schools are in the public domain and need to balance utility and innovation and, in many districts, must respond to serious public accountability.

The stakes are large. The magnitude of the education building business both in the US and the world increases annually.[1,2] More than $20 billion was spent in the US on new elementary, middle and high school construction alone in 2007 (Abramson, 2008). Trade journals, architectural websites, research foundation reports and government documentation show that innovative design is a prime component in the new construction of schools. Architectural firms that specialize in school design publicize that they lead community inclusion in the design process, usually limited to pre-design/charrette stages (AAF, 2008). The school building business includes using POE as a marketing tool for architect and construction firms[3] where (almost exclusively) successes are showcased and awarded. An exception is the US National Clearinghouse for Educational Facilities (NCEF) which makes some public sector evaluations available[4] (Sanoff, 2002). Historically these evaluations consider the facility's physical condition, usage (as a function of area appropriated for each type of use, e.g. classroom, music room, cafeteria, student lounge) and energy use by using POE and evaluation database programmes usually facilitated by professional assessors. The commissioning of buildings with stated budgets for both cost and energy use is increasing. Space utility is a dynamic issue as education styles and populations change quickly (Lighthall et al, 2006).

The issue of signature/innovative designs and their association with educational theory coalesce with stakeholder participation during the design stages but analysis of the utility of these architectural features has not been addressed systematically in POE.

The UK has put an emphasis on determining better design practices based on POE for educational buildings and community involvement in the design process. This process (based on work by the Commission for Architecture and the Built Environment – UK (CABE) and furthered by the Design Quality Indicator – UK (DQI) evaluation process) promotes ways to design more usable educational facilities (CABE, 2006). New and colourful publications[5] show new buildings, innovative interior and exterior spaces and describe their intended use. It does not include POE results that would determine whether the goals could be realized. Analysing the use of space in these new facilities should be a priority in light of the CABE 2006 research report *Assessing Secondary School Design Quality* which includes insightful sections such as:

> *Weaknesses: A large number of schools surveyed failed to function spatially. The survey identifies that teaching, key ancillary spaces and circulation are often inappropriate for their function.* (CABE, 2006, section 7.2)

A school may be designed in accordance with all the conventional and green criteria but in practice may not lend itself to allowing the occupants to use it to its potential. These errors can only be corrected if POE addresses these issues and the results are honestly and openly publicized.

There are school districts worldwide that are committed to evaluating the use of space and user satisfaction (Watson, 2003, 2005). These POE and feasibility studies do not delve deeper than giving a numerical grade to user satisfaction (DKF, 2005). There is no place in the assessments to ponder whether wasted space was produced by the design features.

SUSTAINABILITY: FROM DECLARATION TO PERFORMANCE THROUGH POE

Architect Alexi Marmont took the designers of the new London City Hall to task by questioning the cost, spatial and energy efficiency of this landmark project (Marmont, 2004). Her review of published data suggested that the unique interior and exterior shapes were part of the reasons that led to a good, but not excellent, usability rating. The building cost more than others in its class and user thermal comfort was mixed. Of most concern is the fact that no data pertaining to energy use had been published and maintenance of the building will be relatively costly because of its idiosyncrasies. Touted as a sustainable building, life cycle analysis (LCA) of materials used and energy use data needs to be added to the evaluations already performed. Perhaps sustainability cannot be determined by a single mechanism such as the proposed 'next generation LEED', which incorporates performance and a wide range of LCA metrics, but needs to be professionally evaluated by a group of professionals using a variety of measurements, POE and other post-construction data. The issue of sustainability, holistic by definition, may be too complex to determine by measurements alone.

Obviously user sensibility and satisfaction must play a pre-eminent role in evaluating all types of facilities and therefore they must play an active part in building performance evaluations of all types (Leaman and Bordass, 1999; Wagner et al, 2007; Langston et al, 2008). The questions at hand demand that the occupant can express his/her satisfaction with the immediate workspace as well as give an opinion on how much the built environment is beneficial, neutral or negatively affects the satisfaction rating. Increasingly, buildings are not simply a workplace or a classroom but where people spend the best part of their lives (Baird and Jackson, 2004), with potentially profound effects on health and productivity (Wargocki et al, 1999). Nevertheless it may be unreasonable to include questions about material choices at the post-occupancy stage for all types of buildings. The POE is a tool that must relate to the job at hand. Gordon and Stubbs (2004) touch on the different goals of POE in five case studies of buildings selected for continued long-term review by the AIA's Building Performance Committee. They note that architectural practice Fox and Fowle's selection of a curtain wall of high-performing glass was part of the specification for the LEED Silver residential high-rise development in Manhattan, The Epic (also known as St Francis of Assisi). Even if the glazing was of superior quality and energy efficient relative to other windows, it is less energy efficient and contains higher embodied energy than many opaque wall options. Does the entire wall of the building need to be glazed for aesthetic reasons? In order to maintain sale value? Is it possible to structure questions in a POE to elicit constructive responses from a building's tenants with reference to their views of glazed curtain walls? There are developers of commercial urban projects that ask such questions such as at the Solaire residential tower in New York City's Battery Park City, but they are few and have not been externally evaluated after construction (DOE, 2004).

Achieving comfort in conventional buildings, especially the glass-and-steel blocks characteristic of the past 30–40 years, results in substantial energy consumption and adverse environmental impacts. A survey of 200 detached houses conducted in the cold climatic area of Japan to clarify the characteristics of indoor climate and energy consumption (Genjo and Hasegawa, 2006), showed that the indoor climate in buildings constructed in recent years was better than that in older buildings, and the energy consumption in the former was higher than in the latter. There is a persistent discrepancy between the increasing demand for comfort in buildings and the need to decrease the use of energy (Zeiler and Boxem, 2008). However, under the mounting pressure of energy shortage, one approach to minimize the contradiction is to design sustainable buildings in an informed and responsive way (Zeiler et al, 2008). Therefore, integration between end-user needs and building performance is of significant importance.

POE studies have the potential to clarify discrepancies, loopholes and problems in different ways. They can indicate problems in the design process (for the architect and related disciplines), the operation (for the occupant, user and building manager) or in the building as a system.

Even (or, perhaps, especially) in initiatives that are declared to be green, and for architects who plan for them, POE has an important role to play in providing feedback. A POE study of a solar neighbourhood in Israel (Vainer and Meir, 2005) showed discrepancies between the planners' environmentally friendly intentions and the final outcome. The neighbourhood was constructed in three stages over time. Analysis of quantitative data, such as south-facing fenestration as a percentage of the overall area of each unit, showed a gradual decline over the course of the three-stage construction, substantially restricting the potential for passive heating and natural ventilation, and deviating from initial intentions. Whereas two monitored houses in stage 1 showed minimal or no auxiliary energy use for backup heating in winter and none for cooling in the summer (Etzion, 1994; Meir, 2000a), monitoring of houses in the later stages revealed indoor winter temperatures to be significantly below thermal comfort even with backup heating, and incorporation and operation of air conditioners in the summer, owing to wrong design. The study revealed that whereas the houses in stage 1 were mainly designed by local architects who were acquainted both with the local climate and with the bioclimatic strategies, the latter were designed primarily by non-local architects with little or no acquaintance with the potential provided by the plan, misunderstanding the principles of sustainable design and bringing about the unintended outcome.

The inputs available from POE can also identify where the behaviour of building users undermines their functioning and where the education of users is critical in order to prevent this and increase their capacity to operate features optimally (Hydes et al, 2004). A POE survey of seven energy conserving projects in Israel showed that, to some degree, each of them malfunctioned after several years of occupancy, mainly due to the lack of communication between the architect and users over time, often caused by the introduction of new users (Meir and Hare, 2004). As a result, systems and features were operated inappropriately, leading to poor indoor conditions and eventually to building changes. An evaluation of the refurbishment of four historic buildings dating from the 16th century showed that inherent traditional physical features were abandoned for new technological solutions such as air-conditioning, since users were largely unaware of the potential of the original building features and their potential to modify the indoor environment (Buhagiar, 2004).

A study of office buildings in Austria indicated considerable levels of dissatisfaction with certain aspects of the indoor climate and environmental control systems. Occupants interviewed considered their knowledge of their offices' environmental systems as insufficient and would welcome clarification on the operation of such systems (Mahdavi et al, 2008).

Besides instructions on use and operation, it is necessary to explain to the user the rationale and potential of sustainable design. A survey of a bioclimatic complex in a desert climate showed that although there were detailed instructions on the appropriate operation of buildings and their systems and details (shutters, wind chimney, etc.) in every unit, tenants were often confused and doubtful about the actual effects of such measures (Meir et al, 2007). Actually, not all tenants who are living in green buildings feel committed to the concept of passive heating or cooling. Energy efficient building is hardly just a technology – it truly is a way of life and a tool to achieve a bigger goal. Thus this kind of building should be nurtured by education and not left to self-explanatory tools. POE can identify the where and illuminate the how.

THE RELATION OF POE TO LCA AND GREEN STANDARDS

POEs can supplement life cycle analysis, the set of mechanistic and analogical determinations based on energy use and quantifying the types and amounts of construction materials, increasingly used to compare the impact of buildings (Boecker, 2005; BFRL, 2007). These, it is hoped, can help quantify the carbon emissions from materials used in building and the potential emission savings inherent in using specific construction elements (Huberman and Pearlmutter, 2008). LCA has not been used widely for comparing buildings to date because of the multitude of variables that make up embodied energy calculations and the problems involved in attempting to attribute energy savings to elements that are dependent on how they are operated (Meir and Hare, 2004). Also, some work and public spaces have qualities that may not have an agreed use and are challenging to monitor, such as multistorey atriums (Atif and Galasiu, 2003). User intuition and feedback may play a guiding role in correlating the materials used and the value of the space created. Evaluation of a building's success in supplying a healthy and usable environment by its occupants and users as well as professionally produced appraisals are a necessary component of LCA (Gale, 2008), and this is where POE comes in.

As green buildings and low-energy houses began to catch on, the design community recognized the need for a rating system to assess how green a building is (Hydes et al, 2004). In 2000, the United States Green Building Council (USGBC) launched the first formal framework for rating green buildings in the US – Leadership in Energy and Environmental Design (LEED) (Abbaszadeh et al, 2006). The LEED system, with its

69-point scheme and third-party verification, offered a set of assessments of green buildings, which consisted of sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality (USGBC, 2002). However, it was not developed to be used as a POE tool, and has been criticized for its relative flexibility in mutually compensating items.

In 2002, the California-based Center for the Built Environment developed a web-based survey and accompanying online reporting tools to assess the performance of workspace, identify areas needing improvement and provide useful feedback to designers and operators about specific aspects of building design features and operation strategies from the occupants' perspective. The survey includes the following modules related to IEQ: office layout, office furnishing, thermal comfort, air quality, lighting, acoustics and building cleanliness and maintenance (Zagreus et al, 2004; Abbaszadeh et al, 2006; Kosonen et al, 2008). A seven-point semantic differential scale with endpoints 'very dissatisfied' and 'very satisfied' was used to evaluate occupant satisfaction quantitatively. If respondents indicate dissatisfaction with a survey topic, they branch to a follow-up page where they can specify the source of dissatisfaction. Thus, a web-based IEQ survey has been utilized as a diagnostic tool to identify specific problems and their sources (Kosonen et al, 2008). Furthermore, the survey implementation process is convenient and inexpensive, since the survey is delivered through a website, where occupants are given the ability to evaluate their workplace online. Responses are collected and added to a benchmarking database comprising the records of buildings investigated, enabling the comparison of occupant satisfaction of different buildings transversely.

POE IN DISENTANGLING THE NEXUS OF ENERGETIC, THERMAL AND VISUAL DIMENSIONS

POE becomes important, even essential, given the often unexpected interrelations between various aspects of building function. For example, buildings with sustainable features are not only expected to save energy, especially for heating and cooling, but also to provide their tenants with a better indoor environment. The following case studies focus on the evaluation of building performance relevant to energy consumption, referring to thermal comfort, visual comfort, occupant satisfaction, energy efficiency, etc. The majority of these buildings were designed with a variety of energy saving characteristics regarding the local climatic conditions, for instance, double-skin facade, thermal mass, natural ventilation and passive heating or cooling devices in the light of sustainability principles. The methodology involved in these case studies basically covered both physical measurement and monitoring, and occupants' subjective assessments. Furthermore, a few studies emphasized the comparison between green buildings and ordinary buildings, using an IEQ tool.

Three POE studies (Gossauer, 2005; Pfafferott et al, 2007; Wagner et al, 2007) conducted in Germany investigated green buildings referring to thermal comfort and occupant satisfaction. Although their research targets differed, the findings were similar and interrelated. It is noteworthy that a positive perception of thermal comfort reported by respondents who are working in these green buildings may occur beyond the temperature limits normally set for air-conditioned buildings. Actually, several research projects have demonstrated that occupants in naturally ventilated buildings perceive higher room temperatures as comfortable. Since the current regulations, standards and recommendations of design temperature only refer to air-conditioned buildings, being forced to apply them in the evaluation of green building performance would probably result in an unsatisfactory outcome and restrictions in passive cooling design. The limits of tenants' perception of comfort are important for naturally ventilated and passively cooled buildings.

Additionally, the occupants' ability to control the indoor environment influences their satisfaction. Questionnaires suggested that in the case of no control over one's environment, occupant satisfaction with indoor temperature was relatively lower, although it met the standards of ISO 7730. Obviously, perceived control is different during the different seasons. On the other hand, two studies concerning environmental control systems (Menzies and Wherrette, 2005; Mahdavi et al, 2008) showed that buildings with fully operable windows were marked with higher satisfaction than those without such windows, the former allowing occupants to enjoy natural ventilation and daylight.

Daylighting and visual comfort are fundamental aspects of the indoor environment and energy efficiency in buildings. For tenants, many studies have demonstrated that if daylight is the primary source of lighting, there is a great improvement in productivity, performance and well-being for occupants in general (De Carli et al, 2008). The most used parameter for quantification of daylighting in buildings is the daylight factor (DF) which can be defined as the illuminance received at a point indoor from a sky of known or assumed luminance distribution, expressed as a percentage of the horizontal illuminance outdoors from an unobstructed hemisphere of the same sky (Patricio et al, 2006). Other relevant parameters for the evaluation of daylighting and visual comfort performance in buildings are the uniformity ratio and glare. By introducing daylight into office space through windows and using it as the source of lighting, energy consumption for artificial illumination can be reduced substantially.

A field study in Japan investigated performance and daylighting during the operation phase by surveying visual comfort and energy efficiency in office buildings. Questionnaires and monitoring surveys were conducted in nine office buildings between 2002 and 2007. Installing a large window has the advantage that energy for lighting is saved and visual comfort is improved by introducing natural light and allowing views out (Ito et al, 2008). However, thermal and visual comfort near windows are not always improved – occupants may suffer from excessive heat and glare discomfort (Mochizuki et al, 2006; Ito et al, 2008). South-facing windows are especially problematic due to the penetration of direct radiation and their blinds are often kept shut. In that case, a large window may prove to be largely counterproductive (Ito et al, 2008).

Driven by the need to increase comfort and energy efficiency, double-skin facades (DSF) were developed as an architectural engineering solution that has been adopted mainly in office buildings. Since DSF were initially developed for colder climates to help reduce energy for heating, they can cause overheating problems and increased energy needs for cooling during the summer, as well as in temperate and hot climates, especially if appropriate shading and ventilation devices are not designed or properly operated. Three POE studies showed that blinds and mechanical ventilation systems in DSF can solve glare-related problems or excess solar radiation.

CONCLUSIONS: POE – BETWEEN THE EMBRYONIC AND THE INEVITABLE

In this chapter we have reviewed some of the key aspects of POE and presented a somewhat eclectic and opinionated account of how POE interacts with important debates and issues in making the construction and life cycle of buildings more sustainable. Now is the time to take a step back from the details to look at the big picture regarding the development and institutionalization of POE and its emerging role as a facilitator of sustainable building practices.

Our review of published, conference and web sources shows a rich and increasingly sophisticated set of practices associated with POE – the overall sense is of a field that is at the threshold of maturity, but not quite there yet. Indications of this are that despite a growing awareness of POE principles, procedures and their importance, their use and the way in which they relate to key debates remains erratic. Thus, while the number of studies has grown enormously, they lack agreed-upon protocols, measures and procedures, making comparison difficult. Another indicator of pre-maturity is the distinct but still relatively low level of use of POE in the education of architects and the other professionals involved in the building process.

What does strike us in our review, however, is the extent to which the path toward greater maturity, acceptance, consistency and formalization of POE is inevitable. This is because of the remarkable and increasingly demonstrable potential of POE to serve as an integrator of various realms. It is in this integration role where POE contributes to sustainability in the deeper senses. By integration we mean the following (among others):

- integration between the pre- and post-handover phases in the building life cycle;
- integration of the various stakeholders in the building process – particularly the designer, owner, operator and occupant;
- integration of the various building disciplines with one another;
- the merging of practice with research;
- integration of various tools and, indeed, with the suites of qualitative and quantitative research traditions;
- integration of subjective and objective dimensions of building use and experience, and their measurement;
- the ability to bridge the static performance conceived for the building versus the dynamic functioning when real users interact with and modify these static features;
- bringing conceptions and aspirations closer to actual practices and performances.

New buildings are required to meet increasingly demanding standards with respect to comfort, safety, cost-effectiveness and sustainability, while still allowing creative expression. And they must do so across a time horizon now stretched backwards and forwards in new ways by perspectives such as life cycle analysis. In this milieu, the kinds of integration sketched above are no longer a luxury, but an imperative for survival (Roaf et al, 2005). And this is why we argue that it is inevitable that POE – which can facilitate so many of these forms of integration – will take on an increasing and, ultimately, indispensable role in the building process.

NOTES

1 Foundations and Firms American Architectural Foundation http://www.archfoundation.org/aaf/aaf/Publications.htm
2 Organisation for Economic Co-operation and Development, Directorate for Education, Programme on Educational Building PEB Exchange No 63 – June 2008 and previous journals
3 www.designshare.com, www.learningbydesign.biz/
4 NCEF www.edfacilities.org/
5 www.dqi.org.uk/DQI/Common/PSD-book.pdf

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REFERENCES

AAF (American Architectural Foundation) (2008) *Winter 2008 School Design Institute*, AAF, www.archfoundation.org/aaf/aaf/pdf/sdi.winter08.pdf (accessed 15 July 2008)

Abbaszadeh, S., Zagreus, L., Lehrer, D. and Huizenga, C. (2006) 'Occupant satisfaction with indoor environmental quality in green buildings', in E. de Oliveira Fernandes et al (eds), *Healthy Buildings: Creating a Healthy Environment for People, Proceedings of HB2006 International Conference*, Lisbon, vol III, pp365–370

Abramson, P. (2008) *The 2008 Annual School Construction Report*, School Planning and Management, www.peterli.com/spm/resources/rptsspm.shtm (accessed 2 August 2008)

Amai, H., Tanabe, S. I., Akimoto, T. and Genma, T. (2007) 'Thermal sensation and comfort with different task conditioning systems', *Building and Environment*, vol 42, no 12, pp3955–3964

ASHRAE (1992) *Standard 62 – Ventilation for Acceptable Indoor Air Quality*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA

ASHRAE (2004) *Standard 55 – Thermal Environmental Conditions for Human Occupancy (ANSI Approved)*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA

Atif, M. R. and Galasiu, A. D. (2003) 'Energy performance of daylight-linked automatic lighting control systems in large atrium spaces: Report on two field-monitored case studies', *Energy and Buildings*, vol 35, no 5, pp441–461

Baird, G. and Jackson, Q. (2004) 'Probe-style questionnaire surveys of building users – an international comparison of their application to large-scale passive and mixed-mode teaching and research facilities', in *Proceedings of SBSE Conference Closing The Loop: Post Occupancy Evaluation: The Next Steps*, Windsor, UK, Society of Building Science Educators, 29 April–2 May, CD-Rom

BFRL (Building and Fire Research Laboratory) (2007) *BEES – Building for Environmental and Economic Sustainability*, National Institute of Standards and Technology, Office of Applied Economics, www.bfrl.nist.gov/oae/software/bees/ (accessed 2 August 2008)

Boecker, J. (2005) *Going Green: Where to Find Green Product Information*, AIA Best Practices, http://soloso.aia.org/stellent/idcplg?IdcService=GET_FILE&dID=25505&Rendition=Web (accessed 2 August 2008)

Bordass, W. and Leaman, A. (2004) 'Probe: How it happened, what it found and did it get us anywhere?', in *Proceedings of SBSE Conference Closing The Loop: Post Occupancy Evaluation: The Next Steps*, Windsor, UK, Society of Building Science Educators, 29 April–2 May, CD-Rom

Buhagiar, V. M. (2004) 'A post-occupancy evaluation of manipulating historic built form to increase the potential of thermal mass in achieving thermal comfort in heavyweight buildings in a Mediterranean climate', in *Proceedings of SBSE Conference Closing The Loop: Post Occupancy Evaluation: The Next Steps*, Windsor, UK, Society of Building Science Educators, 29 April–2 May, CD-Rom

CABE (Commission for Architecture and the Built Environment) (2006) *Assessing Secondary School Design Quality*, research report, www.cabe.org.uk/AssetLibrary/8736.pdf (accessed 15 July 2008)

CABE (2007) *A Sense of Place – What Residents Think of Their New Homes*, research report, www.cabe.org.uk/AssetLibrary/10948.pdf (accessed 15 July 2008)

CIBSE (Chartered Institution of Building Services Engineers) (1994) *Code for Interior Lighting*, CIBSE, London

Coulter, J., Hannas, B., Swanson, C., Blasnik, M. and Calhoum, E. (2008) 'Measured public benefits from energy efficient homes', in *Proceedings of Indoor Air 2008 Conference*, Copenhagen, Denmark, 17–22 August

Daioumaru, K., Tanabe, S., Kitahara, T. and Yamamoto, Y. (2008) 'Thermal performance evaluation to double skin facade with vertical blinds', in *Proceedings of Indoor Air 2008 Conference*, Copenhagen, Denmark, 17–22 August

Davara, Y., Meir, I. A. and Schwartz, M. (2006) 'Architectural design and IEQ in an office complex', in E. de Oliveira Fernandes et al (eds), *Healthy Buildings: Creating a Healthy Environment for People, Proceedings of Healthy Building 2006 International Conference,* Lisbon, III, pp77–81

De Carli, M., De Giuli, V. and Zecchin, R. (2008) 'Review on visual comfort in office buildings and influence of daylight in productivity', in *Proceedings of Indoor Air 2008 Conference*, Copenhagen, Denmark, 17–22 August, Paper ID: 112

DKF (Donnell-Kay Foundation) (2005) *School Facility Assessments: State of Colorado*, www.dkfoundation.org/PDF/COSchoolFacilityAssessments-2005April.pdf (accessed 11 July 2008)

DOE (US Department of Energy) (2004) *20 River Terrace – The Solaire*, Buildings Database, http://eere.buildinggreen.com/overview.cfm?ProjectID=273 (accessed 2 August 2008)

Etzion, Y. (1994) 'A bio-climatic approach to desert architecture', *Arid Lands Newsletter*, vol 36, pp12–19

Etzion, Y., Meir, I. A., Pearlmutter, D. and Tene, M. (1993) 'Project monitoring in the Negev and the Arava, Israel', in *Solar Energy in Architecture and Urban Planning, Proceedings of the 3rd European Conference on Architecture*, Florence, Italy, May, Commission of the European Communities, H.S. Stephens and Associates, pp568–571

Etzion, Y., Portnov, B. A. and Erell, E. (2000a) 'A GIS framework for studying post-occupancy climate-related changes in residential neighbourhoods', in K. Steemers and S. Yannas (eds), *Architecture, City, Environment, Proceedings of the 17th PLEA International Conference,* James & James, London, pp678–683

Etzion, Y., Portnov, B. A., Erell, E., Meir, I. A. and Pearlmutter, D. (2000b) 'Climate-related changes in residential neighbourhoods: Analysis in a GIS framework', in K. Steemers and S. Yannas (eds), *Architecture, City, Environment, Proceedings of the 17th PLEA International Conference,* James & James, London, pp781–782

Etzion, Y., Portnov, B. A., Erell, E., Meir, I. A. and Pearlmutter, D. (2001) 'An open GIS framework for recording and analyzing post-occupancy changes in residential buildings: A climate related case study', *Building and Environment*, vol 36, no 10, pp1075–1090

Faruqui Ali, Z., Mallick, F. H., Ford, B. and Diaz, C. (1998) 'Climate, comfort and devotion. A study at the Krsna temple complex, Mayapur, India', in E. Maldonado and S. Yannas (eds), *Environmentally Friendly Cities, Proceedings of the PLEA98 International Conference,* Lisbon, Portugal, June, pp187–190

Frenkel, L., Fundaminsky, S., Meir, I. and Morhayim, L. (2006) 'Post-occupancy evaluation of a scientists village complex in the desert: Towards a comprehensive methodology', in R. Compagnon et al (eds), *Clever Design, Affordable Comfort:*

A Challenge for Low Energy Architecture and Urban Planning, Proceedings of the 23rd PLEA International Conference, Geneva, Switzerland, 6–8 September, pp907–912

Gale, S. F. (2008) *Built to Last: Measuring the Life Cycle of a Facility*, GreenerBuildings, www.greenerbuildings.com/feature/2008/04/10/built-last-measuring-life-cycle-a-facility (accessed 5 September 2008)

Genjo, K. S. M. and Hasegawa, K. (2006) 'Questionnaire survey on indoor climate and energy consumption for residential buildings related with lifestyle in cold climate area of Japan', in E. de Oliveira Fernandes et al (eds), *Healthy Buildings: Creating a Healthy Environment for People, Proceedings of Healthy Building 2006 International Conference*, Lisbon, vol III, pp355–360

Gordon, D. E. and Stubbs, S. (2004) *Building Performance: Where Do We Stand, and Where Are We Going?*, AIA Building Performance Committee Searches for Answers, The American Institute of Architects, www.aiahouston.org/cote/Building%20Performance%20-%20article.htm (accessed 5 September 2008)

Gossauer, E. A. W. (2005) *User Satisfaction at Workspaces: A Study in 12 Office Buildings in Germany*, CISBAT, Lausanne, Switzerland

Huberman, N. and Pearlmutter, D. (2008) 'A life-cycle energy analysis of building materials in the Negev desert', *Energy and Buildings*, vol 40, no 5, pp837–848

Hydes, K. P., McCarry, B., Mueller, T. and Hyde, R. (2004) 'Understanding our green buildings: Seven post-occupancy evaluations in British Columbia', in *Proceedings of SBSE Conference Closing The Loop: Post Occupancy Evaluation: The Next Steps*, Windsor, UK, Society of Building Science Educators, 29 April–2 May, CD-Rom

IAUA (Israel Association of United Architects) (1994) *Bylaws of Engineers and Architects*, IAUA, www.isra-arch.org.il/ (accessed 30 October 2008)

Ito, H., Yuming, W., Watanabe, S. and Tanabe, S. (2008) 'Field survey of visual comfort and energy efficiency in various office buildings utilizing daylight', in *Proceedings of Indoor Air 2008 Conference*, Copenhagen, Denmark, 17–22 August, Paper ID: 309

Kenda, B. (2006) 'Pneumatology in architecture: The ideal villa', in E. de Oliveira Fernandes et al (eds), *Healthy Buildings: Creating a Healthy Environment for People, Proceedings of Healthy Building 2006 International Conference*, Lisbon, vol III, pp71–75

Kosonen, R., Kajaala, M. and Takki, T. (2008) 'Perceived IEQ conditions: Why the actual percentage of dissatisfied persons is higher than standards indicate?', in *Proceedings of Indoor Air 2008 Conference*, Copenhagen, Denmark, 17–22 August, Paper ID: 861

Kowaltowski, D. C. C. K., Pina, S. A. M. G., Wilva, V. G. D., Labaki, L. C., Ruschel, R. C. and Moreira, D. C. (2004) 'From post-occupancy to design evaluation: Site-planning guidelines for low income housing in the state of São Paulo,' in *Proceedings of SBSE Conference Closing The Loop: Post Occupancy Evaluation: The Next Steps*, Windsor, UK, Society of Building Science Educators, 29 April–2 May, CD-Rom

Langston, C., Song, Y. and Purdy, B. (2008) 'Perceived conditions of workers in different organizational settings', *Facilities*, vol 26, no 1/2, pp54–67

Leaman, A. and Bordass, B. (1999) 'Productivity in buildings: The "killer" variables', *Building Research and Information*, vol 27, no 1, pp4–19

LEED Policy Manual (2006) *Leadership in Energy and Environmental Design*, www.usgbc.org/ShowFile.aspx?DocumentID=2039 (accessed 18 March 2008)

Levin, H. (2005) 'Integrating indoor air and design for sustainability', in *Proceedings of the 10th International Conference on Indoor Air Quality and Climate*, Beijing, China, 4–9 September, item 1.7-34

Lighthall, C., Carruthers, W. and Zulli, R. A. (2006) *Renovation Impact on Student Success*, Wake County Public School System, North Carolina

Loftness, V., Hartkopf, V., Poh, L. K., Snyder, M., Hua, Y., Gu, Y., Choi, J. and Yang, X. (2006) 'Sustainability and health are integral goals for the built environment', in E. de Oliveira Fernandes et al (eds), *Healthy Buildings: Creating a Healthy Environment for People, Proceedings of HB2006 International Conference*, Lisbon, Portugal, vol I, Plenary lectures, pp1–10

Mahdavi, A. and Proeglhoef, C. (2008) 'Observation-based models of user control actions in buildings', in *Proceedings of PLEA – Passive and Low Energy Architecture 2008 Conference,* University College Dublin, Ireland, 22–24 October, (electronic version only) paper 169

Mahdavi, A., Kabir, E., Mohammadi, A. and Lambeva, L. (2008) 'Occupants' evaluation of indoor climate and environmental control systems in office buildings', in *Proceedings of Indoor Air 2008 Conference*, Copenhagen, Denmark, 17–22 August

Mallick, F. H. (1996) 'Thermal comfort and building design in the tropical climates', *Energy and Buildings*, vol 23, no 3, pp161–167

Marmont, A. (2004) 'City Hall, London: Evaluating an icon', in *Proceedings of SBSE Conference Closing The Loop: Post Occupancy Evaluation: The Next Steps*, Windsor, UK, Society of Building Science Educators, 29 April–2 May, CD-Rom

McMullen, S. (2007) 'Libraries in transition: Evolving the information ecology of the Learning Commons: A sabbatical report'. *Librarian Publications,* Paper 10, http://docs.rwu.edu/librarypub/10 (accessed 2 August 2008)

Meir, I. A. (1990) 'Monitoring two kibbutz houses in the Negev Desert', *Building and Environment*, vol 25, no 2, pp189–194

Meir, I. A. (1998) 'Bioclimatic desert house: A critical view', in *Environmentally Friendly Cities, Proceedings of the 15th PLEA International Conference*, Lisbon, Portugal, 1–3 June, James & James, London, pp245–248

Meir, I. A. (2000a) 'Integrative approach to the design of sustainable desert architecture: A case study', *Open House International*, vol 25, no 3, pp47–57

Meir, I. A. (2000b) 'Courtyard microclimate: A hot arid region case study', in K. Steemers and S. Yannas (eds), *Architecture City Environment, Proceedings of the 17th PLEA International Conference*, Cambridge, James & James, London, pp218–223

Meir, I. A. (2008) 'Apology for architecture', in S. Roaf and A. Bairstow (eds), *The Oxford Conference: A Re-evaluation of Education in Architecture*, WIT Press, Southampton, Boston, pp33–36 (invited presentation)

Meir, I. A. and Hare, S. (2004) 'Where did we go wrong? POE of some bioclimatic projects, Israel 2004', in *Proceedings of SBSE Conference Closing The Loop: Post Occupancy Evaluation: The Next Steps*, Windsor, UK, Society of Building Science Educators, 29 April–2 May, CD-Rom

Meir, I. A., Pearlmutter, D. and Etzion, Y. (1995) 'On the microclimatic behavior of two semi-enclosed attached courtyards in a hot dry region', *Building and Environment*, vol 30, no 4, pp563–572

Meir, I. A., Motzafi-Haller, W., Krüger, E. L., Morhayim, L., Fundaminsky, S. and Oshry-Frenkel, L. (2007) 'Towards a comprehensive methodology for Post Occupancy Evaluation (POE): A hot dry climate case study', (keynote presentation) in M. Santamouris and P. Wouters (eds), *Building Low Energy Cooling and Advanced Ventilation in the 21st Century, Proceedings of the 2nd PALENC and 28th AIVC Conference*, Crete, II, 27–29 September 2007, pp644–653

Menzies, G. F. and Wherrette, J. R. (2005) 'Windows in the workplace: Examining issues of environmental sustainability and occupant comfort in the selection of multi-glazed windows', *Energy and Buildings*, vol 37, no 11, pp623–630

Mochizuki, E., Watanabe, S., Kobayashi, K., Wei, Y., Tanabe, S., Takai, H. and Shiratori. Y. (2006) 'Field measurement on visual environment in office building daylight from light-well in Japan', in E. de Oliveira Fernandes et al (eds), *Healthy Buildings: Creating a Healthy Environment for People, Proceedings of HB2006 International Conference*, Lisbon, vol II, pp201–206

Morhayim, L. and Meir, I. (2008) 'Survey of an office and laboratory university building: An unhealthy building case study', in *Proceedings of Indoor Air 2008 Conference*, Copenhagen, Denmark, 17–22 August, Paper ID: 933 (electronic proceedings version only)

Nakamura, S., Tanabe, S. I., Nishihara, N. and Haneda, M. (2008) 'The evaluation of productivity and energy consumption in 28 degrees office with several cooling methods for workers', in *Proceedings of Indoor Air 2008 Conference*, Copenhagen, Denmark, 17–22 August, Paper ID: 129 (electronic proceedings version only)

Nicol, J. F. and Humphreys, M. A. (2002) 'Adaptive thermal comfort and sustainable thermal standards for buildings', *Energy and Buildings*, vol 34, no 6, pp563–572

Nordberg, M. (2008) 'Thermal comfort and indoor air quality when building low-energy houses', *Proceedings of Indoor Air 2008 Conference*, Copenhagen, Denmark, 17–22 August

Ochoa, C. E. and Capeluto, I. G. (2006) 'Evaluating visual comfort and performance of three natural lighting systems for deep office buildings in highly luminous climates', *Building and Environment*, vol 41, no 8, pp1128–1135

PassivHaus (2008) www.passivhaustagung.de/Passive_House_E/passivehouse.html

Pati, D. and Augenbroe, G. (2006) 'Modeling relative influence of environmental and sociocultural factors on context-specific functions,' *International Journal of Physical Sciences*, vol 1, no 3, pp154–162.

Patricio, J., Santos, A. and Matias, L. (2006) 'Double-skin facades: Acoustic, visual and thermal comfort indoors', in E. de Oliveira Fernandes et al (eds), *Healthy Buildings: Creating a Healthy Environment for People, Proceedings of Healthy Building 2006 International Conference*, Lisbon, vol II, pp37–42

Pearlmutter, D. and Meir, I. A. (1995) 'Assessing the climatic implications of lightweight housing in a peripheral arid region', *Building and Environment*, vol 30, no 3, pp441–451

Pearlmutter, D. and Meir, I. A. (1998) 'Lightweight housing in the arid periphery: Implications for thermal comfort and energy use', in H. J. Bruins et al (eds), *The Arid Frontier: Interactive Management of Environment and Development*, Kluwer Academic Publishers, Dordrecht, pp365–381

Pearlmutter, D., Etzion, Y., Erell, E., Meir, I. A. and Di, H. (1996) 'Refining the use of evaporation in an experimental down-draft cool tower', *Energy and Buildings*, vol 23, no 3, pp191–197

Pearson, D. (1989) *The Natural House Book*, Conran Octopus, London, UK

Pfafferott, J., Herkel, S., Kalz, D. and Zeuschner, A. (2007) 'Comparison of low-energy office buildings in summer using different thermal comfort criteria', *Energy and Buildings*, vol 39, no 7, pp750–757

Pitts, A. E. and Douvlou-Beggiora, E. (2004) 'Post-Occupancy Analysis of Comfort in Glazed Atrium Spaces', in *Proceedings of SBSE Conference Closing The Loop: Post Occupancy Evaluation: The Next Steps*, Windsor, UK, Society of Building Science Educators, 29 April–2 May, CD-Rom

Preiser, W. F. E. (1995) 'Post-occupancy evaluation: How to make buildings work better', *Facilities*, vol 13, no 11, pp19–28

Preiser, W. F. E. (2004) 'Evaluating Peter Eisenman's Aronoff Center: De-bunked de-constructivism', in *Proceedings of SBSE Conference Closing The Loop: Post Occupancy Evaluation: The Next Steps*, Windsor, UK, Society of Building Science Educators, 29 April–2 May, CD-Rom

Preiser, W. F. E. and Vischer, J. (eds) (2005) *Assessing Building Performance*, Butterworth-Heinemann, Oxford

Roaf, S. (2004) 'Cave Canem: Will the EU Building Directive bite?', in *Proceedings of SBSE Conference Closing The Loop: Post Occupancy Evaluation: The Next Steps*, Windsor, UK, Society of Building Science Educators, 29 April–2 May, CD-Rom

Roaf, S. with Horsley, A. and Gupta, R. (2004) *Closing the Loop. Benchmarks for Sustainable Buildings*, RIBA Enterprises, London

Roaf, S., Crichton, D. and Nicol, F. (2005) *Adapting Buildings and Cities for Climate Change: A 21st Century Survival Guide*, Elsevier Architectural Press, Oxford

Roulet, C. A., Foradini, F., Cox, C., Maroni, M. and de Oliveira Fernandez, E. (2005) 'Creating healthy and energy-efficient buildings: Lessons learned from the HOPE project', in *Proceedings of the 10th International Conference on Indoor Air Quality and Climate*, Beijing, China, 4–9 September

Roulet, C. A., Bluyssen, P. M., Cox, C. and Foradin, F. (2006) 'Relations between perceived indoor environment characteristics and well-being of occupants at individual level', in E. de Oliveira Fernandes et al (eds), *Healthy Buildings: Creating a Healthy Environment for People, Proceedings of Healthy Building 2006 International Conference*, Lisbon, vol III, pp163–168

Sanoff, H. (2002) *Schools Designed with Community Participation*, National Clearinghouse for Educational Facilities, www.edfacilities.org/pubs/sanoffschools.pdf (accessed 25 August 2008)

Silva, F. M., Duarte, R. and Cunha, L. (2006) 'Monitoring of a double skin facade building: Methodology and office thermal and energy performance', in E. de Oliveira Fernandes et al (eds), *Healthy Buildings: Creating a Healthy Environment for People, Proceedings of Healthy Building 2006 International Conference*, Lisbon

Spengler, J. D., McCarthy, J. F. and Samet, J. M. (2000) *Indoor Air Quality Handbook*, McGraw-Hill, New York

Stevenson, F. (2004) 'Post-occupancy – squaring the circle: A case study on innovative social housing in Aberdeenshire, Scotland', in *Proceedings of SBSE Conference Closing The Loop: Post Occupancy Evaluation: The Next Steps*, Windsor, UK, Society of Building Science Educators, 29 April–2 May, CD-Rom

USGBC (United States Green Buildings Council) (2002) *Leadership in Energy and Environmental Design (LEED) Green Building Rating System for New Construction and Major Renovation (LEED-NC)*

Vainer, S. and Meir, I. A. (2005) 'Architects, clients and bioclimatic design: A first POE of a solar neighborhood', in M. Santamouris (ed), *Passive and Low Energy Cooling for the Built Environment, Proceedings of the PALENC 2005 International Conference,* May, Santorini, II, pp1059–1064

Wagner, A., Gossauer, E., Moosmann, C., Gropp, T. and Leonhart, R. (2007) 'Thermal comfort and workplace occupant satisfaction: Results of field studies in German low energy office buildings', *Energy and Buildings*, vol 39, no 7, pp758–769

Wargocki, P., Wyon, D. P., Baik, Y. K., Clausen, G. and Fanger, P. O. (1999) 'Perceived air quality, sick building syndrome symptoms and productivity in an office with two different pollution loads', *Indoor Air*, vol 99, no 3, pp165–179

Watson, C. (2003) 'Review of building quality using post occupancy evaluation', *Journal of the Programme on Educational Building*, OECD, www.postoccupancyevaluation.com/publications/pdfs/POE%20OECD%20V4.pdf (accessed 15 July 2008)

Watson, C. (2005) *Post Occupancy Evaluation – Braes High School, Falkirk*, Scottish Executive, www.scotland.gov.uk/Publications/2006/01/23112827/11 (accessed 15 July 2008)

Wilson, A. and Austin, B. (2004) 'Post occupancy evaluation case study advanced naturally ventilated office', in *Proceedings of SBSE Conference Closing The Loop: Post Occupancy Evaluation: The Next Steps*, Windsor, UK, Society of Building Science Educators, 29 April–2 May, CD-Rom

Woollett, S. and Ford, A. (2004) 'How happy are we? Our Experience of conducting an occupancy survey', in *Proceedings of SBSE Conference Closing The Loop: Post Occupancy Evaluation: The Next Steps*, Windsor, UK, Society of Building Science Educators, 29 April–2 May, CD-Rom

Xiong, Y. (2007) 'The impact of exterior environmental comfort on residential behaviour from the insight of building energy conservation: A case study on Lower Ngau Tau Kok estate in Hong Kong', in *Building Low Energy Cooling and Advanced Ventilation in the 21st Century, Proceedings of the 2nd PALENC and 28th AIVC* Conference, Crete, 27–29 September, vol 2, pp1141–1145

Zagreus, L., Huizenga, C., Arens, E. and Lehrer, D. (2004) 'Listening to the occupants: A web-based indoor environmental quality survey', *Indoor Air*, vol 14 (Supplement 8), pp65–74

Zeiler, W. and Boxem, G. (2008) 'Sustainable schools: Better than traditional schools?', in *Proceedings of Indoor Air 2008 Conference*, Copenhagen, Denmark, 17–22 August, Paper ID: 10 (electronic proceedings version only)

Zeiler, W., Savanovic, P. and Boxem, G. (2008) 'Design decision support for the conceptual phase of sustainable building design', in B. W. Olesen et al (eds), *The 11th International Conference on Indoor Air Quality and Climate*, Copenhagen, Technical University of Denmark, vol CD, pp1–8