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Customized performance evaluation approach for Indian green buildings

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ABSTRACT

The green building movement in India is lacking an important link: ensuring that the design intent of such buildings is actually realized. This paper undertakes an exploratory investigation to develop and test a customized building performance evaluation (BPE) approach (I-BPE framework) for the Indian context. As academia is considered to be an initial primary outlet of BPE, a survey of experts is conducted to investigate the drivers and barriers for implementing BPE-based methods in educational curricula. The I-BPE approach is tested in a case study building to gain insights for refining the underlying methods and processes for conducting further BPE studies in the context of India. The expert survey reveals the lack of trained people for teaching BPE as a key challenge to its adoption, implying that trained people are needed as much as frameworks. To enable widespread adoption of I-BPE in India, what will be necessary is a new cadre of building performance evaluators who can be trained (or up-skilled) through formal or continuing education. This will need to be driven by both policy (energy code) and market transformation ('green' rating systems). A series of delivery routes are suggested to enable rapid and deeper learning.

KEYWORDS

Building performance evaluation (BPE); education; energy efficiency; green buildings; post-occupancy evaluation (POE); India

Introduction

India has the third largest economy in the world and is growing rapidly: energy consumption has almost doubled since the year 2000. Buildings in India currently account for 41% of the country's total final energy consumption and there is great potential for continued rapid growth and urbanization (key drivers for energy trends). Green building certification councils have clearly seen this as an opportunity. The Indian Green Building Council (IGBC) claims that India has the second largest registered green building footprint (with over 4.71 billion square feet), and over 4363 projects registered for green building ratings (as of November 2017) (IGBC, 2018). However, the green building movement in India is lacking an important link: ensuring that the design intent of such buildings is actually realized.

Research continually demonstrates that green building rating and certification systems do not always ensure greater energy performance (Sawyer, de Wilde, & Turpin-Brooks, 2008), occupant satisfaction (Alborz & Berardi, 2015) or better indoor environmental quality (IEQ) over conventional buildings (Tham, Wargocki, & Tan, 2015). As is seen extensively in the UK (Bordass, Cohen, & Field, 2004), United States (Navarro, 2009), and Germany (Calì, Osterhage, Streblow, & Müller, 2016), to name a few, despite improvements in the building fabric and the deployment of innovative services and systems, a significant gap between predicted and actual performance in non-domestic and domestic buildings is observed, leading to higher-than-expected energy use (Bordass, Cohen, Standeven, & Leaman, 2001; Demanuele, Tweddell, & Davies, 2010), among other issues. Though there is little evidence of this performance gap in India (Sabapathy, Ragavan, Vijendra, & Nataraja, 2010), it is hypothesized that it is at least as prevalent as in other countries, and will persist as more green buildings are built to meet both the demand of urbanization and the global concern for greenhouse gas emissions reduction.

One way of identifying and addressing the performance gap is through building performance evaluation (BPE), which is a process of systematically comparing the actual performance of buildings against expected performance based on feedback and evaluation at every

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phase of building delivery, ranging from strategic planning to occupancy, through the building's life cycle (Preiser & Vischer, 2005). While BPE can cover the entire life cycle of the building (including construction, post-construction, early occupancy and in-use stages), post-occupancy evaluation (POE) is limited to the in-use stage of a building (Preiser, 2005). Although POE/BPE has been established since the 1990s and is used internationally, no standardized protocol has gained international dominance (Li, Froese, & Brager, 2018). The Center for the Built Environment (CBE) at the University of California – Berkeley has developed various methodologies for BPE in the categories of IEQ, heating, ventilation and air-conditioning (HVAC) systems, building envelope and human interactions, and whole-building energy. Performance criteria have been derived from the CBE's occupant satisfaction database; the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Performance Measurement Protocols (PMP); the Leadership in Energy and Environmental Design (LEED), and others (Goins, 2011). In Japan (Kato, Roux, & Tsunekawa, 2005), Australia (Carthey, 2006), and the Netherlands (Mallory-Hill, Preiser, & Watson, 2012), POE has been used to test whether client goals are met, to strengthen the connection between facility management (FM) and user satisfaction, and to provide feedback to future projects for improvement. In Brazil, a review of design and construction drawings, walkthroughs, unstructured interviews, questionnaires, and the measurement of environmental conditions have been used to evaluate the designers'/builders' consideration of the occupant (Ornstein, Andrade, & Leite, 2005). Studies with similar methodological applications, *e.g.* plan and specification review, behavioural observation, questionnaires, codes and standards assessment, and IEQ assessment, have been applied in Hong Kong, China (Lee et al., 2012), and Singapore (Wong & Jan, 2003).

In the UK, initiatives such as the Post-occupancy Review of Buildings and their Engineering (PROBE) (Bordass et al., 2001; Usable Buildings Trust, 2015) investigated the performance of 23 buildings (1995–2002) covering a wide range of BPE methods including design review and walkthrough, fabric and systems review, energy and environmental data collection, and occupant survey (leading to the development of building use studies (BUS)[1] survey questionnaires). More recently (2010–14), the UK government's Technology Strategy Board (now Innovate UK) ran a national research programme on BPE to address the performance gap challenge in new domestic and non-domestic buildings. A significant output of this programme has been a consistent methodology that has been carried through 101 studies, 48 of which cover non-domestic buildings, providing insights into the performance of design strategies, building fabric, actual energy use, construction methods, occupancy patterns, handover and operational practices (Palmer & Armitage, 2014). Despite the range of BPE studies, a recent international review of BPE studies by Li et al. (2018) concluded that currently BPE is in the first stage of adoption, *i.e.* only innovators employ BPE.

The Indian sustainability rating system, Green Rating for Integrated Habitat Assessment (GRIHA) version 2015, includes a performance assessment requirement that reviews whether energy systems, water systems and solid waste-management systems of the building are performing as predicted and they match the information provided at the time of award of a provisional GRIHA rating. However, there is no comprehensive performance evaluation of a building mandated during the operational stage from a technical and occupant perspective. LEED-India has optional credit paths that prescribe POE/aftercare or elements of BPE after certification has been awarded (USGBC, 2017a, 2017b). This is a good start for verification of design intent, but can be limited, especially when not mandatory. Academia currently has a significant role in demonstrating BPE in India, although industry needs to play a stronger role in driving its development and implementation. Since it appears that green building certification programmes are moving slowly in this direction, industry will need to become familiar with the concepts and methods to participate in the process.

The discourse on sustainability, energy efficiency and green buildings in India has gained more attention in recent years due to government initiatives through model curricula, which has led to inclusion of environmental science for architecture (Council of Architecture (COA), 2008), energy efficiency for engineering (All India Council for Technical Education (AICTE), 2018c), and social, cultural and climatic theory behind vernacular design (Desai, 2010). Architectural education has shown some integration of sustainability concepts (Manu et al., 2012) due to the government's greater focus on education, the Energy Conservation Act and the development of the Energy Conservation Building Code (ECBC), and the increasing popularity of green building rating systems (*e.g.* GRIHA and LEED-India). In fact, the COA (2008) has suggested electives pertaining to green building and rating systems, building performance and compliance, and building systems integration and management. Although the BPE exists in research settings in other countries, the authors argue that it should be more widely used in India, and the primary gateway to this greater use is through the formal educational system for professionals.

Within this context, this paper describes the development and initial testing of a customized BPE approach for the Indian context (I-BPE) to evaluate the real performance of green buildings. A survey of experts investigates the drivers and barriers for implementing BPE-based methods in architectural and engineering (A&E) formal and continuing educational (CE) curricula. A series of delivery routes are suggested to enable rapid and deeper learning. The proposed I-BPE approach is 'road tested' for a case study building to gain insights in order to refine the underlying methods and processes for conducting further BPE studies. The present study directly addresses two themes from the special issue on energy management: (1) the role of building design and construction in creating low-carbon, resource-efficient, and thermally comfortable housing and workplaces; and (2) the role that occupants/inhabitants/organizations play in building energy performance and the shaping of energy demand.

The paper is structured as follows. A critical review of literature is next undertaken to investigate the integration of building performance in A&E education curricula in India, and to identify the methods and tools used for assessing real building performance in research studies. The I-BPE framework is formulated along with possible delivery routes to enable its adoption in education, research and industry. An online survey of experts is conducted to understand whether the proposed BPE methods are relevant in an Indian context, and the barriers to their implementation. Finally, the proposed I-BPE approach is tested for a case study green building through a postgraduate dissertation by one of the co-authors (MD), followed by a discussion of the implementation of BPE in India.

Building performance in India: initiatives in education and research

In order to design a customized BPE approach for India as a prelude for its widespread adoption, it is vital first to examine the current teaching of building performance in educational curricula in India, what can be learnt from similar initiatives, and what methods have been used in published studies on assessing real building performance in India. Although the fit between architectural education and industry is not necessarily found to be tightly coupled (Cuff, 1991), the present authors argue that if the issues of building performance are to accepted and adopted by industry, then building performance needs to be taught in higher education and CE (for existing professionals).

The AICTE is a national-level apex advisory body in India responsible for prescribing model curricula for undergraduate (UG) and postgraduate (PG) courses in engineering and technology. Civil engineering is a stream that is most closely related to buildings. At the UG level, facilities management is a small part of the 'Civil Engineering – Societal & Global Impact' course, while the 'Energy Science & Engineering' course includes a few modules introducing the concepts of energy efficiency, sustainability, green buildings and energy audits. The degree of this 'integration' is reduced further in the PG curriculum, where 'Electrical Energy Conservation and Auditing, Control Systems Design' and 'Energy Conservation and Management' are proposed as professional elective courses (AICTE, 2018a, 2018b, 2018c). Similarly, the COA, which is charged with the responsibility of regulating architectural education across India, prescribes building sciences and applied engineering-related core courses at the UG level that include 'Climatology' and 'Environmental Lab'. The latter involves measurements; documentation and recording; and analysis and design using hand-held devices and computer software focusing on thermal, light and ventilation performance of built environment. The COA also prescribes a list of professional elective courses such as 'Green Buildings and Rating Systems', 'Sustainable Cities and Communities'; 'Building Performance and Compliance' and 'Building Systems Integration and Management' (COA, 2008). Interestingly, there is a lack of literature in the public domain that discusses how these model curricula (minimum standards for architecture and engineering domains) are interpreted by educational institutions in India. These include 114 technical universities, 2213 colleges offering degrees in engineering and technology, and 145 architectural colleges, which collectively enrolled 2.1 million UG and 100,000 PG students in 2016–17 and produce 400,00 graduates each year, according to figures from the Ministry of Human Resource Development (MHRD) (2017).

The USAID-funded ECO-III project's (2000–10) (Kumar, 2010) review of environmental design and building services courses across 28 architectural institutions in India revealed that institutes offering courses in environmental design field (covering building physics, energy simulation) have not integrated it well with the design studios (Manu et al., 2012). Courses were taught as standalone electives and little effort was made to incorporate the knowledge and principles into the overall conception of building structure and design, or to incorporate the practical aspects of design into the teaching methodology of the courses. Since the COA's curriculum model offers enough flexibility to include or exclude any course or change course credit structure, it is important to review international examples that have integrated building performance in A&E education.

International methods for teaching and learning BPE can potentially be applicable in the Indian context. These include the use of building physics principles; standards/practices and protocols for field observations and evaluation taught through background, enquiry, questions and hypothesis; building evaluation and analysis; and synthesis and design implications as practised through the 'Vital Signs Project' in the United States (Benton, Huizenga, Marcial, Hydeman, & Chace, 1996; Kwok & Grondzik, 1995). Building on the 'Vital Signs Project', the 'Agents of Change Program' (AOC, 2005) (coordinated by the University of Oregon's Department of Architecture and funded by a grant from the US Department of Education Fund for the Improvement of Post-Secondary Education (FIPSE) in 2000–05) used intensive training sessions, live case studies and toolkit loans to prepare students to assume their roles as teachers, architects and stewards of the built environment. In Germany, building life-cycle considerations are linked to BPE education (Schramm, 2011). In the UK, a 'learning-by-doing' BPE teaching-and-learning approach is practised in some universities (Gupta, 2014; Sharpe, 2013; Stevenson, 2014), wherein university buildings are used as case studies for BPE, acting as living labs. To communicate the experience and outcomes of BPE studies in the UK, Janda and Topouzi (2013, 2015) have suggested the approach of storytelling, since stories have the power to make sense of things and to engage more people and provide a framework for understanding, educating and passing on knowledge. In the built environment, 'learning stories' provide practical illustrations from the delivery of building projects captured through BPE studies.

Although the application of BPE-related methods in A&E education seems to be lacking, the application of these methods in academic research in India has been published, though not extensively. A review of the literature to identify the methods and tools for studying actual building performance in India reveals two discrete sets of studies: one on field studies of thermal comfort (FSTC) and the other on POE/BPE. The FSTC differs from the BPE in that it is concerned with the occupant's immediate response to a building, referred to as 'right here, right now' surveys (Kumar, Mathur, Mathur, Singh, & Loftness, 2016; Thomas, 2017), and measurements taken in relation to that response (Nicol & Roaf, 2005) involving spot readings of environmental variables. POE studies, on the other hand, gather a long-range memory of the occupant's response to the indoor environment for a glimpse of the building's performance (Nicol & Roaf, 2005) and to answer certain questions such as: Is the building performing as intended? and How can it be improved? (Bordass, Leaman, & Eley, 2006).

Interestingly most of the building performance studies in India are focused on FSTC: understandably so, considering the temperature extremes in some locations, ongoing criticism of comfort specifications in the National Building Code (NBC) among other standards (Indraganti, 2010a, 2010b; Kumar et al., 2016; Sharma & Ali, 1986), and the rising popularity of air-conditioning (AC) (Dhaka & Mathur, 2017; Manu, Shukla, Rawal, Thomas, & de Dear, 2016). Across the various studies on modern apartments (Indraganti, 2010a), vernacular houses (Singh, Mahapatra, & Atreya, 2010), and offices (Manu et al., 2016), common methods emerge that include thermal comfort questionnaires, interviews, temperature and relative humidity (RH) logging, and spot measurement of indoor environmental parameters, although there is an inconsistency in the periods of study and time intervals, and in the inclusion or exclusion of certain methods, periods of study and time intervals of data collection.

The POE/BPE studies differ from the FSTC studies in that, in addition to many of the above methods, they included: a long-range questionnaire on work area satisfaction, general thermal comfort, indoor air quality (IAQ), *etc.* (such as the BUS survey) (Manu et al., 2016); a review of project information; and interviews with key stakeholders (owner/developer, design team and FM). In a limited number of studies, information regarding energy consumption was gathered through metering and energy bills (Thomas & Baird, 2006), and only one study was found (Bhanware, Jaboyedoff, Chetia, Maithel, & Reddy, 2017) that went beyond the above studies by including a design and system installation review, seasonal energy monitoring for two different seasons, and data logging of electricity distribution with IEQ spot measurements. Interestingly, despite the growth of green buildings in India (driven by green rating systems), there appears to be a gap in pre-occupancy BPE studies, examining the as-built performance through *in situ* testing of the building fabric thermal performance, and review of services installation and commissioning.

Developing the I-BPE framework

Insights gathered from the literature review inform the initial development of the I-BPE framework for the Indian context. The I-BPE framework consists of the I-BPE methodological approach and potential delivery routes for its adoption in A&E education, research and industry. To formulate the I-BPE methodological approach, the methods used for performance evaluation of buildings in India were compared with those commonly used for BPE studies internationally and in the UK, including the authors' experience in BPE work, notably through Innovate UK's BPE Programme (Gupta & Gregg, 2014, 2016; Gupta, Gregg, & Cherian, 2013; Gupta, Gregg, Passmore, & Stevens, 2015). The evaluation, with input from experts in India, helped to prioritize methods and indicate which may or may not be relevant for the Indian context. Based on this and the graduated levels of POE (indicative – what have we got?; investigative – what does it mean?; diagnostic – what can we do and what can we learn?) promoted by Preiser (2013); and the numerous BPE studies undertaken by experts in the UK (Cohen, Standeven, Bordass, & Leaman, 2001; Palmer, Terry, & Armitage, 2016; Watson & Thomson, 2005; Wingfield, Bell, Miles-Shenton, & Seavers, 2011), the I-BPE framework is proposed in Table 1, comprising five ('need-to-know') study elements covering both technical and non-technical aspects of building performance.

The I-BPE study elements include: 'review of design intent' through design documentation and interviews with the design and construction team; 'technical building survey' covering inspection of the building fabric, energy systems and controls; 'energy assessment' using annual energy bills/meter readings, monitoring of utility meters, sub-metering and monitoring of individual plug loads; 'measurement of indoor environment' using spot measurements of internal and external temperature and RH to continuous monitoring of specific variables such as volatile organic compounds (VOCs); and 'occupant feedback' using a questionnaire survey, diary, interviews and focus groups to assess occupant comfort, perceptions and experiences of the indoor environment. A detailed description of each BPE method included in the I-BPE framework is shown in Appendix A in the supplemental data online. Methods such as *in situ U*-value testing, co-heating tests and air-pressure testing were excluded, since buildings in India are not designed to be airtight, and it is neither easy nor cheap to access heat flux sensors in India. Despite some methods being excluded, the I-BPE framework is not different from what might be proposed for any other country, which is why feedback from experts and case study application are necessary to customize the framework for the Indian context.

Li et al. (2018) suggest that since the purpose and associated methods in POE are highly case dependent, it makes it difficult to have a standardized protocol for all POE projects. For this reason, each study element in the I-BPE framework adopts a graduated approach (from levels 1 to 4) of increasing complexity and detail, *i.e.* level 1 is the basic method to implementing the

Table 1. Building performance evaluation in an Indian context (I-BPE) framework showing the building performance evaluation (BPE) study elements and associated methods and tools.

	Time and expertise required				
Number	**BPE study elements**	**Level 1**	**Level 2**	**Level 3**	**Level 4**
1	Review of design intent	Collection of available design data, metering strategy, details of building and its use	Review of building services and energy systems	Interviews with key stakeholders, *e.g.* designer, owner, developer	Walkthrough with key stakeholders, *e.g.* designer, owner, developer
2	Technical building survey	Inspection of build quality and services using photographic/video documentation	Controls interface survey	Review of installation and commissioning of services – performed as a walkthrough with (or without) a knowledgeable guide (*e.g.* facility/building manager, owner, designer)	Assessment of the building fabric using infrared thermography
3	Energy assessment (consumption and generation)	Meter readings/energy bills for one year	Monitoring of utility meters: analysis of energy demand profiles	Sub-metering of energy use, *e.g.* energy generation, cooling/ heating, hot water, lighting, equipment	Electricity plug load monitoring of individual appliances
4	Environmental monitoring	Temperature and relative humidity (RH) spot readings (internal and external) (coincide with the occupant survey)	Temperature and RH loggers/monitoring (internal and external, including weather station data download)	Additional parameters spot read/ logged, *e.g.* CO_2, lux, noise, wind speed	Additional parameters spot read/logged, *e.g.* carbon monoxide (CO), PM_x (particulate matter), bio-aerosols, volatile organic compounds (VOCs) (depending on objectives, *e.g.* indoor air quality (IAQ) studies)
5	Occupant feedback	Occupant satisfaction survey (perception of indoor environment and control), *e.g.* building use studies (BUS)	Semi-structured interview (individual occupants)	Thermal comfort diary (thermal sensation and thermal preference of occupants)	Focus group (collective) with occupants to discuss common questionnaire findings in more depth

BPE element and higher levels are to be added to the preceding levels for a deeper investigation. Given the graduated approach, the I-BPE framework can be easily customized for studying different buildings, depending on the availability of data and resources. For example, level 1 methods alone could be applied to 'data poor' buildings (Janda, Bottrill, & Layberry, 2014) (for which little information is available about the design intent or actual performance and/or limited access is allowed for conducting the BPE study), while levels 3 and 4 could be deployed in buildings that are more 'data rich' (buildings for which good data on design intent or actual performance, generally through automatic meter recording (AMR), are available such as energy models and access to the buildings and occupants is provided for undertaking the BPE study). Bringing flexibility in the I-BPE framework should also help with its adoption.

To facilitate the adoption of the I-BPE framework in A&E education, research (for students) and CE (for professionals), a series of delivery routes are suggested to enable rapid and deeper learning (Figure 1). These include one-day workshops (to train the professionals); week-long courses (summer/winter schools); an 8–10-week classroom-based course/module (A&E education); and a 16-week intensive UG/master's dissertation (research). Note that the suggested routes for integrating I-BPE in education are not a recommendation for an overhaul for the curriculum, but a starting point for trialling I-BPE through academia. Since professionals (architects, engineers, consultants) are constrained by time, a one-day training workshop may be more suitable for them to rapidly learn about building performance, while deeper learning can happen through the week-long summer/winter school and teaching course. The four-month dissertation route offers students and staff a means of conducting a deeper engagement with the subject.

As importing methods from foreign countries could be problematic, the I-BPE approach is further refined through the expert survey and case study. The expert survey was selected to obtain expert opinion about the BPE methods and their appropriateness for India, while the case study application (the first of several case studies to follow) was intended to test the BPE methods on the ground through the research dissertation route.

Research methods

The present study adopts an exploratory investigation to refine the proposed I-BPE framework by conducting an online survey of experts on the drivers and barriers for implementing BPE-based methods in A&E education, followed by a case study application of the I-BPE framework by a PG student to road-test the I-BPE approach as a research tool.

Expert survey

An online survey[2] was formulated to gather expert opinion about the methods proposed in the I-BPE framework and the limitations for their adoption. The survey was distributed via email to experts (approximately 400) in the building sector in India through a network shared between the authors. The survey format, as opposed to focus group, for example, was selected to cover as much of India as possible. The survey is a non-probability, convenience sample from a shared database of connections; however, prior knowledge of BPE of the respondents was unknown. The survey is a qualitative, exploratory study to gain a glimpse of the status of BPE in academia and industry in India, and to understand a level of acceptability regarding some of the methods included in the I-BPE. It was constructed using Google Forms and was open for just under four weeks from mid-December 2017 to mid-January 2018. The professional background of the experts covered academics, industry professionals (architects, engineers, green building consultants), construction professionals and policy-makers.

A total of 75 experts responded to the survey (a response rate = 18.8%). Of these, seven were located outside India; these were excluded to reserve analysis for responses from experts currently living and working in India. Interestingly, each non-India response was from a different country: Australia, Belgium, Germany,

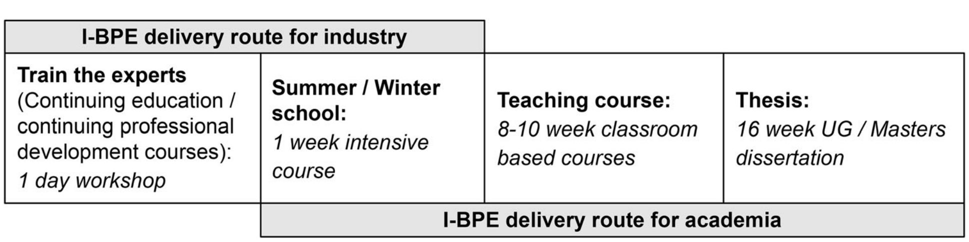

Figure 1. Delivery routes for building performance evaluation in an Indian context (I-BPE) framework for industry and academia.

Indonesia, South Africa, the UK and the United States, indicating a widespread interest in the subject. This left a final response count of 68 experts from India. Figure 2 shows the city, state and climatic zone represented by the respondents. Most respondents (80%) were based in the composite ($n = 32$) and warm-humid ($n = 22$) climatic zones, since these have a wide geographical coverage in India, with a smaller representation in the hot-dry ($n = 7$), temperate ($n = 5$) and cold ($n = 2$) climates.

Many respondents had an architectural and design background, but most considered their professional expertise to be a mix of academic and industry professional (Figure 3). Most respondents also had 10 or more years of experience in the field of energy efficiency or green building. In addition, all but three respondents had some level of prior knowledge of BPE. Most of those with extensive BPE experience were those with both practice (architectural) and academic experience. All respondents with extensive BPE experience had at least six years of experience in energy efficiency/green building; the majority had 10 or more years of experience.

A limitation of the survey is the small number of respondents, considering the size of India and the

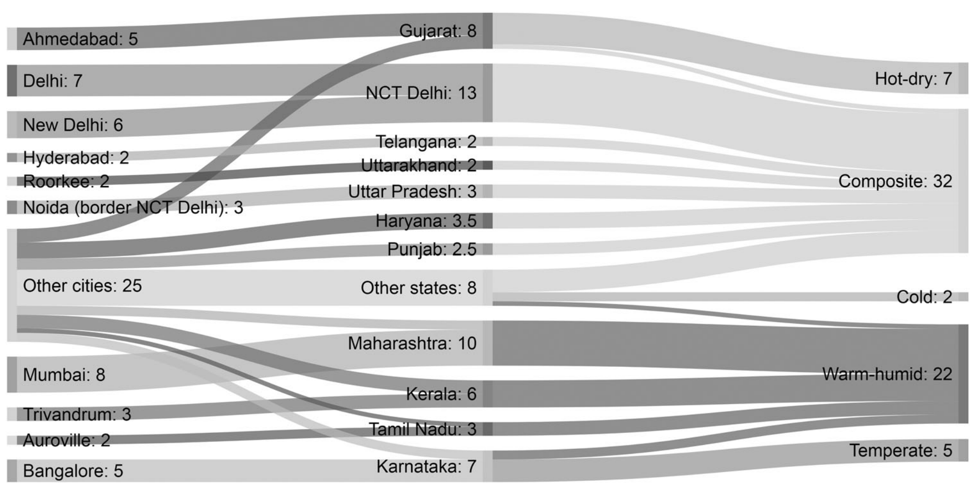

Figure 2. City, state and climate zones represented by respondents.

Note: NCT = National Capital Territory; one city, Chandigarh, is shared by both Punjab and Haryana; cities located in the cold climate zone are on the border of the cold zone and another zone; cities and states with only one representation are grouped into 'other' categories.

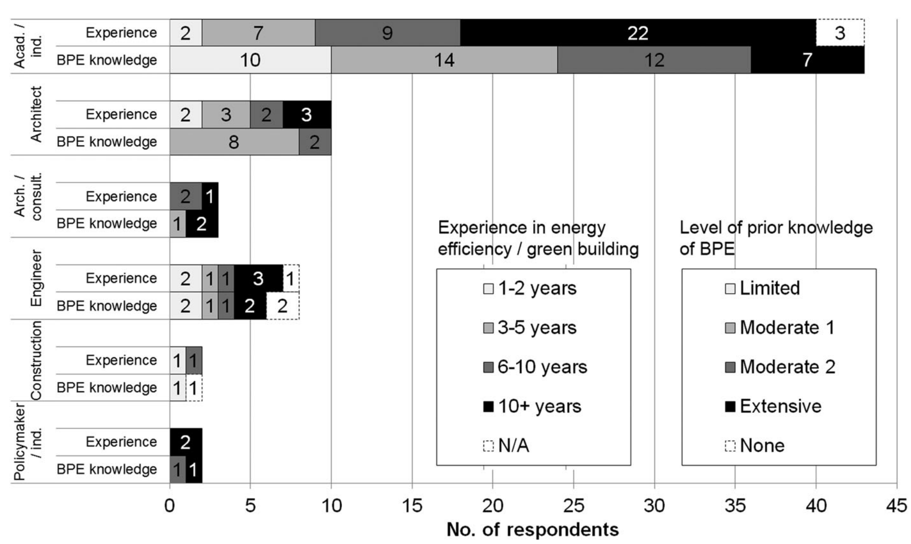

Figure 3. Professional expertise of respondents, experience in energy efficiency/green building and prior knowledge of building performance evaluation (BPE) for the respondents.

Note: Many respondents had multiple categories of professional expertise. Acad./Ind. = academic/industry professional; Arch./consult. = architect/green building consultant; Policymaker/ind. = policy-maker/industry professional. Industry refers to the building industry. Prior knowledge classifications: Limited = 'I have only studied the concept and methods'; Moderate 1 = 'I have some applied knowledge of the methods'; Moderate 2 = 'I have performed at least one BPE/POE'; and Extensive = 'I have performed more than one BPE.'

expected number of professionals in the building industry. However, since the survey is meant to only provide a glimpse into the knowledge and use of BPE methods and to collect opinion on the proposed BPE methods, it is considered sufficient for the purpose. The small response rate can partially be attributed to the short period of time within which the survey was to be completed and the limited reach of contacts. In addition, web surveys are considered to be inferior in response rates compared with other modes, whereas one meta-analysis (Manfreda, Berzelak, Vehovar, Bosnjak, & Haas, 2008) found an average response rate of 11% for web-based surveys.

Architects far outweighed the engineering or construction professionals in the survey (note that academic is a cross-over category for many professionals and therefore not separated from the individual's professional designation). Though numbers of registered professionals could not be compared (59,000 registered architects as of May 2018;[3] engineers (*e.g.* civil) numbers are unknown), academic intake numbers show that as of October 2017, according to the AICTE, in approved institutions there were a total of 13,000 architecture students and almost 2 million 'engineering and technology' students.[4] Though *engineering and technology* covers a broad spectrum, it is estimated from these numbers that engineers in the building industry far outweigh architects. Due to this uneven representation within the different fields and small representation by non-architects in the expert survey, no breakdown in response by expertise is provided. Following the expert survey, the framework was tested on a case study building (more will follow in time).

Case study testing

The I-BPE methodology is tested on a case study green building as part of a PG dissertation (by one of the co-authors (MD)), with the intent to provide feedback on the relevance and effectiveness of the I-BPE methods as a learning tool in the Indian context. A key aim of the case study application is to better understand the challenges in applying the methods and tools of the I-BPE methodology, and how these may be addressed if necessary for undertaking further BPE studies in an Indian context.

A case study green building (MUJ) in a university in Jaipur (composite climate) (Figure 4) was selected, as it was certified as LEED Platinum and GRIHA 5-star rated. Owing to the short length of the dissertation (four months), the case study building needed to have been occupied for at least one year to ensure that one year of energy data were available and the building users were well acquainted with the building and energy systems. The MUJ building has a total area of 35,600 m^2 with 47% conditioned area and a window-to-wall ratio (WWR) of 23%. The building has academic functions (teaching, laboratories, offices, meeting rooms), and is occupied from 08.00 to 18.00 hours, by 4000 occupants, of which 3700 are students. Despite the green credentials, there is no AMR system (data poor); meter readings are manually recorded every day.

The building was studied during the winter season (2018) for 14 days in early February 2018 using the I-BPE approach to match the timeline of the dissertation and access to the case study. Table 2 shows the BPE work plan for the two-week field study period. To perform the occupant survey, an already customized 'monsoon' version of the BUS survey was obtained for use from the Usable Buildings Trust (UBT), which included questions about occupant perception of their indoor environment in the monsoon season, in addition to the summer and winter seasons. Furthermore, the interview questions (for occupants and facility manager) were customized for the Indian context. This customization required the removal of questions pertaining to heating and the addition of questions pertaining to cooling and humidity control. As an example, a question was added to assess whether the occupants experienced over-cooling in the building. An example of customization for the FM/design team interview was the inclusion of a

Figure 4. Case study green building in Jaipur, India.

Table 2. Building performance evaluation in an Indian context (I-BPE) implementation plan for case study building.

Timeline	Activity
Day 01	Walkthrough and interviews with the facility manager Photographic survey
Day 02	Installing data loggers Thermal imaging – building envelope
Day 03	Survey – ground and first floors
Day 04	Survey – second and third floors
Day 05	Survey – catch up Check data loggers
Day 06	Visit and recording details of the photovoltaic system
Days 07–08	Spot measurements and illuminance over the grid
Days 09–10	Survey of controls and user interfaces and illuminance over the grid
Days 11–12	System installation and commissioning review
Day 13	Catch-up day
Day 14	Removing data loggers

question exploring 'whether there were changes to the wall assemblies or internal layout of the building', since wall assemblies can change from design during construction in India and internal layout is almost always different from what is proposed in the design drawings due to large degrees of freedom during construction to change design specifications.

The two research methods, expert survey and the case study application, were not designed to inform each other, but to offer complementary perspectives (opinion of experts and road-testing) for refining the I-BPE framework for the Indian context.

Results

Insights from the expert survey

The analysis of the expert survey responses revealed useful insights for the introduction of I-BPE in the Indian green building movement. A total of 65 of the 68 respondents agreed that BPE is necessary in India, and when asked to comment further on this, 50 'yes' respondents provided the following reasons why BPE is necessary in India:

- validate assumptions/prove certification compliance and design effectiveness ($n = 17$)
- energy performance/management and sustainability ($n = 16$)
- improve performance through improved design process/feedback to inform practice of what works and what does not ($n = 8$)
- raise climatic design awareness ($n = 6$)
- data collection/benchmarking ($n = 3$)

However, the perceived need for BPE does not necessarily mean that it will become common practice given the range of following challenges revealed by the survey. As shown in Figure 5, most respondents considered 'lack of trained professionals to teach BPE' to be the greatest challenge (among the options). In addition to the provided options, four other challenges emerged, including (1) regulatory limitations; (2) overloaded curricula with no room for more courses; (3) lack of background physics courses to set the groundwork for BPE; and (4) lack of awareness about the usefulness and benefits of BPE (three comments with this opinion).

While most respondents considered BPE to be appropriate for both A&E education (Figure 6), a large proportion (85%) of the respondents considered BPE education to be appropriate as primary coursework in both UG and PG (master's) programmes (64%).

The expert survey explored deeper with 53 academic respondents, who stated they were involved with an academic institution in India. This cohort of respondents was given an additional set of questions on their

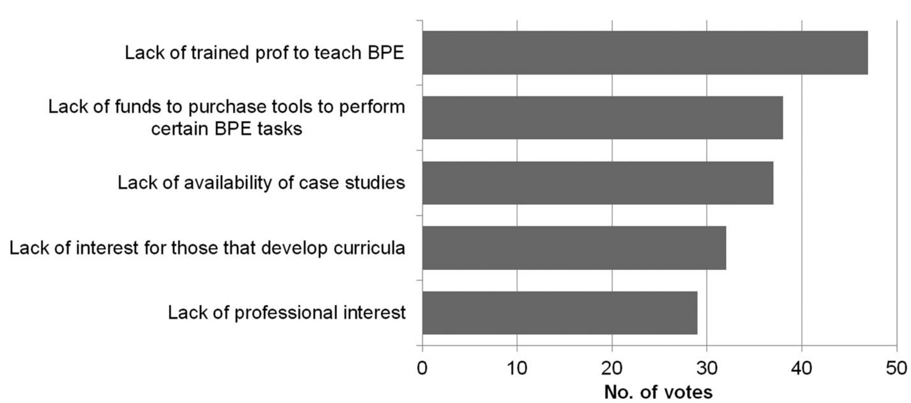

Figure 5. Challenges for embedding building performance evaluation (BPE) in higher education (architectural, engineering).

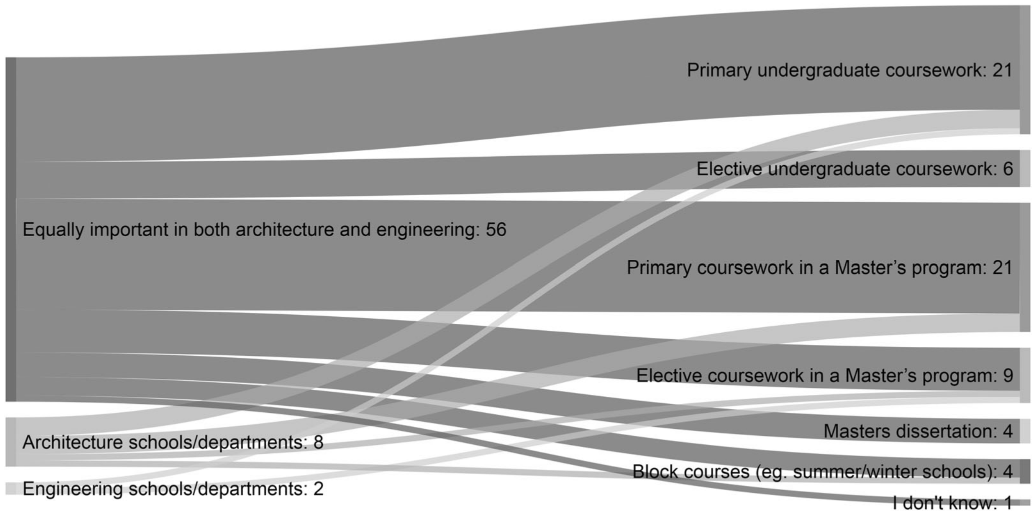

Figure 6. Scope of embedding building performance evaluation (BPE) education in undergraduate and master's programmes ($n = 66$).

institutional arrangements for teaching BPE with the purpose of getting a glimpse of the concepts and methods taught given a lack of literature on the subject. Only five of these respondents were from the same two universities. Of the total 50 educational institutions represented by the 53 respondents, 89% have programmes that teach green building and sustainability, whereas 68% and 62% have programmes in which building services and building physics/science are taught respectively. Courses on energy management are found to be most lacking at 30%.

When queried further regarding what building performance-related methods were taught in the courses, the majority, 49%, responded that thermal comfort and occupant survey were applied, while only 34% have programmes in which environmental monitoring/measurement is applied. Again, most lacking was the application of energy monitoring/measurement at 25%. This finding is corroborated by previous research by Manu et al. (2012), which showed that although most academic institutions in India have laboratories hosting tools and equipment for teaching and exploring design concepts, there was a lack of diagnostic and performance evaluation equipment. Furthermore, despite a large interest in BPE from the survey sample, 30% of the academic respondents represented universities with no course on the BPE methods. The larger application of thermal comfort methods as opposed to energy monitoring/measurement reflect the focus of building performance studies on FSTC, as shown by the literature review.

Figure 7 shows the perceived importance of different BPE methods, wherein the most important methods

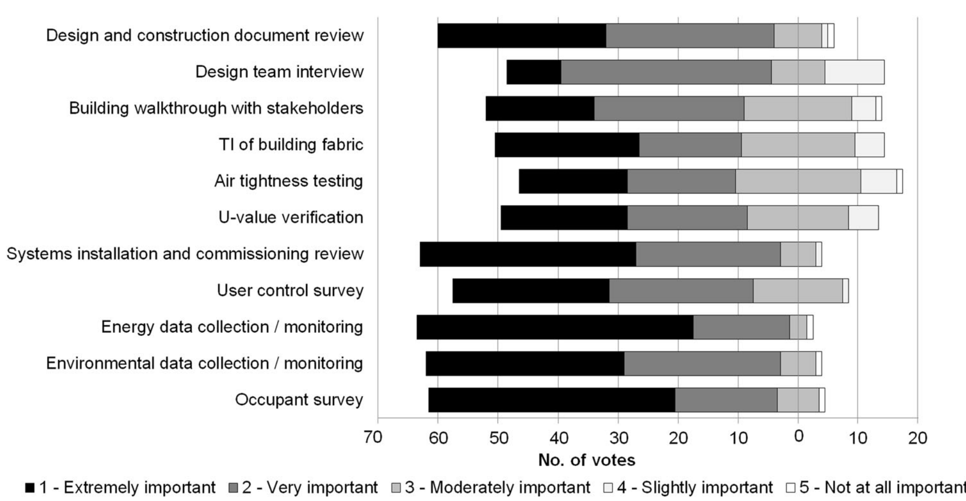

Figure 7. Relative importance of building performance evaluation (BPE) methods as perceived by the experts (n = 68).
Note: TI = thermal imaging survey.

were found to be energy data collection/monitoring and occupant survey, while design team interview and air tightness testing were considered least important.

Table 3 shows the weighted importance of each method based on responses for each respondent's BPE experience. To add weight, the percentage of respondents for each category was multiplied by a weighting factor (5 for 'extremely important', 4 for 'very important' *etc.*); three respondents with no experience were excluded. Most levels of experience shared common ideas about BPE methods; however, interestingly, those with extensive experience in BPE considered the building fabric assessment methods to be the least important with the least overall weight among all experience levels. Table 4 does the same, but is based on respondents' climatic zones. Air-tightness testing and thermal imaging were perceived to have a high level of importance amongst respondents from the cold and temperate climates, while these were considered least important amongst all methods for the hot–dry climate, indicating the influence of local climate on the selection of BPE methods. The survey findings reflect the opinions of the warm–humid and composite zones as most respondents represent these zones (80% combined), which geographically cover most of India. Post-occupancy (in-use stage) investigation period (*e.g.* energy and environmental monitoring and occupant survey) appears to be most important for respondents.

A key aim of the expert survey was to investigate specific barriers to the adoption of BPE methods included in the I-BPE methodology. Five barriers were predefined, along with an open-ended option for respondents to add any number of barriers for each BPE method. The barriers listed below are in the order of highest to lowest voted (along with corresponding BPE method for which the barrier had the highest count in parenthesis); preference for the first two barriers far exceeded the others:

- required expertise to perform an evaluation task (air tightness testing, system installation and commissioning review, and energy data collection/monitoring – a three-way tie)
- time required to perform an evaluation task (occupancy survey)
- cost of equipment (thermal imaging)
- availability of equipment on the market (*U*-value verification)
- low return on investment (dissemination of findings to professionals and policy-makers)

Air-tightness testing and energy data collection were found to have the greatest number of barriers, while the design team interview had the least.

Overall, the key barrier to fostering BPE in education and industry (practice) was found to be the 'lack of policy initiatives that require measuring real building performance' ($n = 47$), followed by 10 fewer votes for 'industry is shy of exposing themselves to liability risk'. The least voted barrier was 'identifying and recruiting suitable buildings' ($n = 20$). The predefined barriers from which to choose were (listed in voted order):

- lack of policy initiatives that require measuring real building performance
- industry is shy of exposing itself to a liability risk
- professionals often do not like to have their work judged by other experts
- difficult or expensive to hire experts with the necessary skills to teach BPE
- finding the time and resource to conduct BPEs
- additional fees are required for conducting a BPE

Table 3. Weighted importance by respondent experience ($n = 68$).

Building performance evaluation (BPE) method	All (100%)	Extensive (17%)	Moderate 2 (24%)	Moderate 1 (33%)	Limited (21%)
Occupant survey	**4.5**	**4.5**	**4.3**	**4.6**	4.4
Environmental data collection/monitoring	4.3	4.2	4.1	4.5	4.4
Energy data collection/monitoring	**4.6**	**4.6**	**4.3**	**4.7**	**4.6**
User control survey	4.1	4.3	4.1	4.2	3.9
Systems instal and Cx review	4.4	4.3	**4.4**	**4.6**	4.3
U-value verification	3.9	3.7	3.9	3.9	3.9
Air tightness testing	3.7	3.7	3.9	3.6	3.9
Thermal imaging survey (TI) of the building fabric	3.9	3.7	3.8	3.9	4.1
Building walkthrough with stakeholders	3.8	3.8	3.4	4.0	4.0
Design team interview	3.7	3.7	3.4	3.7	4.0
Design and construction document review	4.2	4.1	3.9	4.3	**4.5**

Notes: Cx = commissioning.
Different shades indicate different ranges, *e.g.* the largest range of 4.3–4.7 is the darkest shade for easier legibility.

Table 4. Weighted importance by respondent climatic zone ($n = 68$).

Building performance evaluation (BPE) method	All (100%)	Hot–dry (11%)	Warm–humid (32%)	Composite (47%)	Temperate (8%)	Cold (3%)
Occupant survey	**4.5**	4.3	**4.6**	**4.4**	4.4	**4.5**
Environmental data collection/monitoring	4.3	4.0	4.5	4.3	4.4	4.5
Energy data collection/monitoring	**4.6**	**4.9**	**4.7**	**4.5**	4.4	4.0
User control survey	4.1	4.0	4.1	4.2	4.2	4.0
Systems installation and Cx review	4.4	**4.4**	4.4	**4.5**	**4.6**	4.0
U-value verification	3.9	3.3	4.0	3.9	**4.5**	4.0
Air tightness testing	3.7	3.1	3.8	3.7	**4.5**	**4.5**
Thermal imaging survey (TI) of the building fabric	3.9	3.4	4.0	3.8	4.0	**4.5**
Building walkthrough with stakeholders	3.8	3.6	3.8	3.9	3.8	4.0
Design team interview	3.7	3.6	3.8	3.6	4.0	3.5
Design and construction document review	4.2	4.3	4.1	4.2	4.4	**4.5**

Note: Cx = commissioning.

- changing the design/construction brief to integrate BPE studies in projects
- making changes in architectural or engineering curricula to include is bureaucratic and requires approval from a number of parties
- identifying and recruiting suitable buildings

As an open-ended question, when the respondents were asked to provide any additional barriers they thought were missing, the most mentioned ($n = 15$) barrier was 'lack of awareness of the need for BPE throughout industry and policy'. This barrier can, in fact, be the root cause for several of the aforementioned barriers.

Case study testing of the I-BPE framework

To demonstrate the working of the I-BPE framework as a research tool, all five BPE study elements were applied to a real case study green building in Jaipur, as part of a PG dissertation. Table 5 shows the various I-BPE methods applied to the case study building and the corresponding tools used for implementing the methods. Owing to the occupied status of the building, duration of the BPE study and access to design documentation, it was not possible to apply all the four levels of each study element. Instead, the graduated approach developed for each BPE study element was used to select suitable methods that could be applied for evaluating the performance of the case study building, in line with the availability of the design documentation, duration of the field study (14 days, in this case), access to the building and occupants. For instance, while the *technical building survey* study element was carried out through all four levels covering building services and building fabric testing; the study elements on 'review of design intent', 'energy assessment' and 'occupant feedback' were implemented through two levels each. On the other hand, the study element on 'environmental monitoring' was conducted through levels 1–3 covering both spot measurements and logging of environmental variables.

Though the case study building could be considered data poor (typical of buildings in India and probably most buildings outside India), the manual meter readings and access to bills allowed for a basic assessment of energy performance and, in turn, a comparison of the building's green target versus the building's actual annual consumption. The review of design documentation showed that the expected performance goals (set by the green rating systems) for the case study building were primarily focused on *asset* performance covering building geometry and system performance and did not directly address the *operational* aspects such as set-points, mode of operation (mixed mode) and occupancy schedules. The differences between asset and operation may be of greater significance in the Indian context due to more variability in the way buildings are operated. Differentiating between asset and operational performance will help one analyze the data more effectively, and lead to more appropriate corrective measures.

The energy performance index of the case study building was measured at 26.5 kWh/m^2/year, while the annual solar electricity generation was 3% higher than the requirement of LEED Platinum rating, likely providing a buffer for future efficiency loss. The monitored spaces in the case study building were found to be thermally comfortable for the monitored period, according to the NBC (BIS, 2016). Most spaces had acceptable noise levels, except for open office spaces and classrooms on the second and third floors. Average illuminance levels according to NBC 2005 were met, and 82% of occupants surveyed felt satisfied with the overall lighting.

Table 5. Building performance evaluation (BPE) methods and tools used for evaluating the performance of the case study green building.

		Time and expertise required			
Number	**BPE study elements**	**Level 1**	**Level 2**	**Level 3**	**Level 4**
1	Review of the design intent	Collected drawings and documents from the architect and consultants, including LEED and GRIHA rating documents	Review of building services and energy systems	Interviews – NOT USED	Walkthrough – NOT USED
2	Technical building survey	Reviewed installation and operation of HVAC system, lighting, ventilation and photovoltaic (PV) system — *Tool: digital camera*	Controls interface survey — *Tools: digital camera, usability survey checklist*	Walkthrough and interview with the facilities management team. Multiple walkthroughs carried out each to assess the installation of systems and use, building design, and use of building — *Tools: questionnaire, video camera, digital camera*	Interior and exterior thermal imaging — *Tool: FLIR TI camera TG165*
3	Energy assessment (consumption and generation)	Meter readings/energy bills for one year	Monitoring of utility meters – NOT USED	Sub-meter readings provided by the facilities manager	Electricity plug load monitoring – NOT USED
4	Environmental monitoring	Spot readings, instantaneous globe temperature, RH — *Tools: Testo 540, Extech heat stress meter*	Temperature and RH sensors on the ground, first and third floors in all orientations for two weeks — *Tools: HOBO U12-012 data loggers, Tiny tag CO_2 logger/logging frequency: 5 min*	Additional parameters spot read/ logged, *e.g.* CO_2, lux, noise — *Tools: Testo 540 lux meter, Fluke 922 air flow meter, android app for the sound meter*	Additional parameters – NOT USED
5	Occupant feedback	Occupant satisfaction survey: 174 responses (78% response rate) — *Tool: BUS questionnaire, consent forms*	Semi-structured interview (individual occupants)	Thermal comfort diary – NOT USED	Focus group – NOT USED

Note: BUS = Building Use Studies; GRIHA = Green Rating for Integrated Habitat Assessment; HVAC = heating, ventilation and air-conditioning; LEED = Leadership in Energy and Environmental Design; RH = relative humidity.

The control interface survey showed that while fan and lighting controls were perceived to be well designed and easily accessible, lecture rooms and offices did not have access to thermostat control, which affected the local management of the thermal environment. Overall, 79% of occupants surveyed (n = 174) felt that the design met their needs, supported by the continuous engagement of the FM team in managing the operation of the building to meet the design targets. For the building to perform better, recommendations included introduction of a properly commissioned building management system that can provide the FM team with real-time environmental and energy data, provision of local thermostat controls and optimizing the use of blinds (unless direct glare is caused) to increase day light in the building. As can be seen, although the case study is not radically different from other buildings that may be studied in India or elsewhere, the BPE study provides insights about making it better. More case studies are currently underway, and will be used to validate the findings from the MUJ case study.

Lessons from the BPE case study: customizing the I-BPE approach

Important lessons emerged from the case study that can help to inform the process and methods for conducting further BPE studies (as a research tool) in the Indian context. These lessons arise from a context where Indian buildings are built in a design and construction environment that has fewer documentation of design decisions, larger degrees of freedom during construction to change design specifications, fewer tested and certified products used in construction, less formalized building operation, and a limited access to expensive equipment for doing performance evaluation.

This is why before a building is selected for a BPE study it is vital to ensure that adequate and accessible design documentation is available, which includes targets on expected energy performance (and, where possible, calibrated energy models) with which to compare the actual performance. Adequate access and permission to the building, its occupants, FM and the design team is necessary to affirm 'whether the building is worth bothering with', as also recommended by Leaman, Stevenson, and Bordass (2010). A sufficient amount of time should be allocated for review and analysis of the green rating system documentation in order to better understand any unique design features of the building that can be evaluated by monitoring or survey. A significant amount of researcher time was spent in securing the necessary documentation and permissions for conducting the BPE study of the case study. This could be reduced in future with a more targeted selection.

As most Indian buildings are mixed mode (the use of AC is limited to extreme seasons and natural ventilation (NV) mode is used when outdoor conditions are favourable), it is vital to conduct the field study in both AC and NV modes to assess building performance as the outdoor conditions change. Drawing conclusions based on observations from one operation mode may lead to an incomplete assessment. The environmental monitoring plan should be designed well before the site visit for installing the sensors (data loggers). This will ensure that all formal permissions from various stakeholders (building owner, FM team, occupants) are gained beforehand. The monitoring plan should offer flexibility for revision in line with feedback from the FM team, and customization to verify specific performance aspects (such as ventilation rates and illuminance levels) included in the green building rating systems and certification.

There are also useful lessons drawn for the methods included in the I-BPE framework. To understand the working of the entire case study building, especially its energy and management systems, multiple walkthroughs of the building were necessary along with a series of meetings and interviews with the FM team. These efforts need to be adequately resourced in the BPE study. On-site data gathering about the operation and control of the energy systems, in the form of written notes, photographs or videos, provided valuable contextual data to the researcher while analyzing the monitoring data. Although green rating systems encourage submetering to disaggregate energy use, the practice of submetering is not a common feature in green buildings in India. This means that more information needs to be gathered through walkthrough surveys or interviews with the building managers.

Imported questionnaires such as the BUS survey required modification for climate and cultural considerations for implementation in the Indian context. Pilot runs with small groups of occupants were found to be helpful in validating the revised questionnaire, although this needs to be scheduled in the planning of the BPE study. In order to create a good response rate for the occupant survey, it was vital to inform occupants about the purpose and relevance of the survey during a previous visit. The BPE team can provide the occupants with a brief introduction to the survey form. This helped to secure occupant 'buy-in' and gain 'informed consent' for the survey. The BPE researcher could not simply drop off and collect the questionnaires, but had to 'hang around' while respondents completed the survey questionnaire to assure them that their response was important for the study. It was also realized that organizing an occupant focus group was not practically possible on-site due to space and time constraints, although interviews with a sample of occupants helped to gather insights about the reasons for their (dis)satisfaction with the case study building. Irrespective of the feedback methods used, occupants needed to be constantly encouraged to talk about their perception of the building, its facilities and indoor environment.

Discussion

The expert survey revealed a perceived need for BPE (by some professions), and that it might be introduced into the educational curriculum of A&E, although it may not become common practice, as observed in the UK. According to Stevenson (2014), there is an ethical argument to integrating BPE into architectural (and engineering) education as there is a professional 'duty of care' to provide a building that performs as claimed, modelled and/or certified to perform. A BPE that delivers useful findings that either validate or provide a path to correction is an essential component of design analysis and should be seen as inherent to the design process that is taught in schools (Stevenson, 2014). Li et al. (2018) suggest that the building industry (*e.g.* trade organizations) would need to support the integration of BPE into A&E education and, likewise, industry professionals could be educated through a CE approach. In a rapidly developing country such as India, there should be a heightened sense of urgency for the widespread adoption of BPE, which will likely need to happen in both the education and building industry symbiotically, ideally driven by policy and/or market transformation. Reasons for this can be seen in the barriers and drivers for the uptake of building information modelling (BIM) in the United States (Sabongi & Arch, 2009) and the UK (McGough, Ahmed, & Austin, 2013), wherein a top-down requirement (government buildings) was put in place to initiate the professional uptake of BIM. Although the realization was slow, it became apparent that (formal and continued) education needed to provide the BIM training for new professionals.

Likewise, the drive for studying real building performance in India may come from current policy initiatives such as the ECBC; the Ministry of New and Renewable Energy's (MNRE) programmes focusing on the use of renewable energy sources in buildings; and the Sustainable Habitat Mission under the National Action Plan on Climate Change (UNEP SBCI, n.d.), as well as green building rating systems which are considered to be the most successful market transformation mode for high performance buildings in India (Rawal, Vaidya, Ghatti, Manu, & Chandiwala, 2013). The I-BPE framework can support these policy and market-based initiatives by assessing and improving the performance of HVAC and renewable energy systems (such as rooftop solar) and their influence on occupant experience and comfort.

In this context, Rawal et al. (2013) have proposed a third-party evaluator (TPE) model for code compliance checks for the ECBC, and BPE activities are likely to need a similar TPE effort. The existing building certifications offered by both the GRIHA and IGBC are available to all buildings (previously certified as well as not certified), thus opening the certifications to a very large market. The I-BPE framework, therefore, provides a clear path and method for conducting existing building reviews that could be very useful to the GRIHA and IGBC existing building certifications through a TPE model. Where the BPE is used, clients expect the architect to pay, while the architect expects the client to pay (Stevenson, 2014); the certification fees may address the barrier of who will pay for the BPE. The TPE model will also require large-scale training of professionals, the up-skilling of academic staff and introduction of BPE in the educational curricula, in line with the delivery routes suggested for the I-BPE. As shown by an existing Indian model, the Fairconditioning initiative Academic Curricula Integration Project (ACIP)[5] to minimize the use of energy-intensive AC in buildings is partnering with A&E colleges to offer Training of Trainers (ToT) and Certificate Programmes in content pertaining to green building design principles, the ECBC and sustainable cooling technologies (Rougemont & Gilani, 2015).

The application of the I-BPE approach to the case study green building (institutional) provided usable evidence for its potential application, whether there is a 'data-rich' or 'data-poor' situation. However, the discrepancy between design stage energy models that focus on asset performance and make assumptions about the building operation (that are best guesses at the time of design or mandated by the enforcement authorities) and BPE studies that focus on operational performance will need to be addressed by using the model inputs to focus on the causes that may lead to sub-optimal performance. This will also avoid the rush to compare (uncalibrated) design-stage models with in-use energy performance, thereby eluding a false sense of the energy performance gap.

In addition to the implementation potential of the I-BPE and technical aspects of comparing designed and actual performance, the fundamental barrier of lack of awareness of the BPE in industry and academia in India needs to be overcome, possibly through the approach of storytelling, which not only entertains but also has the power to spark emotion, to make sense of things and also to educate (Janda & Topouzi, 2013, 2015). In sparking emotion, people may understand better what they must do as they are emotionally engaged, while in making sense of things, the storyteller can engage more people and provide a framework for understanding the story, and in educating, people may apply and pass on the knowledge they have gained. The BPE studies of real-world case study buildings offer 'learning stories' that lie between the technical potential or the design intent and what is achieved in practice or during use (Janda & Topouzi, 2013, 2015). Professional bodies such as the COA and the Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE), and green rating systems (such as IGBC and GRIHA) could encourage early adoption of the BPE amongst their membership through learning stories, which have the potential to demonstrate the impact of the BPE studies of case study buildings, both in terms of finding ways to improve performance and benefit owners where the actual performance falls short of expectation, and in terms of recognizing commissioning and operation practices that allow building performance to exceed design expectations. This will not only realize the value of work done but also encourage strengthening of the relationship between industry professionals, academics and policy-makers.

Conclusions

The present study has undertaken an exploratory investigation to develop and test for the first time a customized BPE approach for the Indian context (the I-BPE framework) in order to evaluate the real performance of green buildings, using an expert survey and a case study building. The case study testing of the I-BPE approach provided insights for refining the underpinning methods such as using building surveys for understanding energy use in the absence of sub-metering and the inclusion of occupant perceptions about over-cooling in surveys, as well as the process of conducting BPE studies by ensuring better access to design documentation, assessment of mixed-mode operation of buildings and a deeper engagement with occupants. The expert survey revealed a key challenge to the widespread adoption of BPE is the lack of trained professionals to teach

BPE. This implies that trained people are needed as much as frameworks.

To verify whether green buildings in India perform as intended, what will be needed is a 'new' cadre of building performance evaluators (or third-party evaluators – TPEs) who are competent across a relevant range of technical and social aspects of building performance. These evaluators can be trained (or up-skilled) through one or more of the delivery routes suggested (training workshops, summer/winter schools, teaching courses, dissertations) as part of formal or CE. Ultimately, it is hoped that the I-BPE framework will help to build trust in the industry, which is currently adverse to the exposure of the liability risks resulting from actual building performance. For this to happen, it is necessary first to raise awareness about BPE through case studies, the results of which can help to influence academia, practice and policy as it 'would be naive to expect local, regional, and/or national policy level change without building evidence cases' (Gilani, 2017, p. 68).

Given the experience of implementing BPE in other countries, it seems unlikely that the BPE in India can be driven solely by the certification requirements of green building rating systems. This needs further support through a national policy framework that supports, enables and incentivizes the study of real performance of buildings. This will help to inform policy-making and policy evaluation as well as support industry in the development of low-energy and low-carbon solutions (*e.g.* smart meter roll-out and energy demand management policies/practices) which are beginning to happen in some metropolitan cities in India (Kumar, 2018). The experience of BPE in other countries also shows that the highly relevant outcomes of BPE studies may not naturally filter their way through to policy-makers. Understanding the insights gathered through BPE will require increased policy-maker effort.

Notes

1. The BUS methodology is an established way of benchmarking levels of occupant satisfaction within buildings using a structured questionnaire where respondents rate various aspects of the indoor environment and control on a scale of 1–7. The questionnaire prompts respondents to comment on the building's design and image, occupant control, comfort and daily use of the building features through a historic perspective of use (ARUP, 2014). BUS has developed a version for the Indian context, which also includes questions about the indoor environment in the monsoon season in addition to summer and winter seasons.
2. For the survey, see https://goo.gl/forms/I7Hwepgd1FUN9xyo2/.
3. See https://www.coa.gov.in/index1.php?lang=1&level=1&lid=46&sublinkid=33/.
4. See https://www.facilities.aicte-india.org/dashboard/pages/dashboardaicte.php/.
5. See http://www.fairconditioning.org/acip/.

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