Selection of Indicators for Post Occupancy Evaluation (POE) of Sustainable Dormitories

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ABSTRACT

Numerous higher education (HE) institutions in the United States (US) have created sustainability agendas, including the construction of sustainable buildings. More than 200 US HE institutions have at least one LEED certified building on their campus. With the growing student population and corresponding need to house them, the construction of new dormitories is on the rise nationwide. Among the recently constructed buildings, dormitories hold the largest median square footage. In an effort to assess if sustainable dormitories are actually performing in a sustainable way, a series of indicators for post occupancy evaluation (POE) has been selected. POE indicators have been chosen through a review of widely adopted rating systems and scientific literature. This paper discusses the methodology for the selection of these POE indicators. The selected indicators address a range of topics including water and energy consumption, indoor environmental quality, and behaviour of occupants. Moreover, possible indicators for specific technologies such as building energy management systems and building automation control systems have been examined. The framework proposed in this paper provides a comprehensive methodology that captures technical and non-technical components in order to measure sustainability of dormitories.

KEYWORDS: Post Occupancy Evaluation, Sustainable Performance Indicators, LEED, Dormitories.

1. INTRODUCTION

The United States (US) buildings sector is the largest contributor of resource consumption and depletion, accounting for more than 30% of greenhouse gas emissions and 41% of primary energy use (USDOE, 2013). With the need for sustainability higher education (HE) owners have started to adopt sustainability principles for their new facilities. More than 200 HE owners in the US created sustainability agendas, and have at least one LEED certified building on their campus (Princeton Review, 2012). Among the recently constructed buildings, dormitories hold the largest median square footage (Princeton Review, 2012), and often they aim to be more and more sustainable. In order to support this trend, the present study develops a post occupancy evaluation (POE) framework to assess the sustainability of dormitories.

LEED provides guidance on the design and construction of building projects targeting sustainable practices, but it does not require POEs (USGBC, 2009). However, in the last release of LEED standards, reporting of water and energy consumption in the 5-years after the occupancy of the building has been added. This new requirement shows that POE is gaining momentum, also among standards developed to support design and construction stages. However, simply reporting water and energy consumption is not sufficient to obtain the whole performance behaviour of a building. For this scope, sets of POE indicators are necessary to ensure that buildings are behaving sustainably. POE provides a tool to measure the performance of buildings, in terms of meeting design intent and occupant satisfaction. In fact, the gap between actual and modelled performance has often highlighted the need for POE (Bordass et al., 2010). POEs aim to answer two questions: how is the building working, and is the actual performance intended (Leaman, 2003, Hadjri and Crozier, 2009).

Assumptions made by designers dictate the post occupancy state, but are rarely re-examined for accuracy and applicability in practice (Bordass et al., 2010). Furthermore since building performance is rarely monitored, correction measures are seldom implemented whereas, the lack of POEs perpetuates energy and water waste and potential occupant dissatisfaction (Bordass et al., 2004, Bordass et al., 2010).

POEs provide many benefits including: (1) aide communication between stakeholders; (2) create mechanisms for quality monitoring, providing knowledge when buildings do not meet design intent; (3) provide data and knowledge for future designs and key decisions; (4) support development of policy for design and planning guides; and (6) hasten the learning process within organizations by building on successes and not repeat failures (Brown et al., 2010, Bordass et al., 2010).

Even though POEs provide numerous benefits, the uncertainty and difficulties in the selection of indicators and feedback techniques have slowed their adoption (Bordass et al., 2001, Cicelsky et al., 2009). The construction industry fragmentation also hinders POE adoption (Bordass, 2000, Hadjri and Crozier, 2009, Riley et al., 2010). Another obstacle to POEs is that a 'one-size fits all POE' does not exist; therefore POEs should be tailored to specific building applications (Turpin-Brooks and Viccars, 2006, Bordass et al., 2006, Hadjri and Crozier, 2009, Riley et al., 2010, Leaman and Stevenson, 2010).

There are various types of POEs including: (1) indicative: general inspection of building performance by experienced personnel; (2) investigative: in-depth study of building performance, surveys and interviews of stakeholders, and comparison of findings to similar facilities; and (3) diagnostic: sophisticated data collection and analysis, physical measurements, surveys and interviews of stakeholders (Turpin-Brooks and Viccars, 2006).

This study aims to create a POE framework composed of indicative and investigative methods, to monitor the performance of dormitories. The POE indicators presented in this paper aim to be a comprehensive performance framework. The inclusion of key stakeholders (designers, facilities managers, residential life and occupants) and triangulation between quantitative and qualitative data will aide in creating a complete performance evaluation (Robson, 2011).

2. METHODOLOGY

2.1 POE indicator selection

The methodology followed for the selection of POE indicators encompassed a literature review of widely adopted sustainability rating systems and published scientific papers. The research areas in this literature belonged to general applications of POEs (non-academic specific), POEs in HE applications, impact of stakeholders on the building performance, and impact of specific technologies (i.e. impact of building automation control systems (BACS) or building energy management systems (BEMS)).

The selection of POE indicators took also into account the level of importance given to the different parameters in sustainability rating systems, studies and papers; the applicability of indicators in the post occupancy phase of a dormitory also played an important role.

The rating systems that were considered include: LEED (USGBC, 2009), BRE Environmental Assessment Method (BREEAM, 2008), Comprehensive Assessment System for Built Environment Efficiency (CASBEE, 2010), Living Building Challenge (LBC, 2012), and Green Globes (2012). This wide selection allowed a wide point of view in sustainability parameters.

Indicators impacting overall performance not addressed in previous sustainability rating systems, but highlighted in scientific literature, were also included (i.e. occupant behaviour and education, consumption feedback mechanisms, and building maintenance management).

2.2 POE collection

Depending on the type of POE indicator, the collection of its associated data may require quantitative and/or qualitative techniques. Qualitative data collections include face-to-face and online surveys, often tied to Likert scales or open-ended questions; on the other hand, methods for quantitative data involve the collection of actual data through billing information, meter readings, physical measurements, which in this paper will be compared with design and LEED documentation.

To create a comprehensive building performance evaluation, the involvement of key stakeholders is considered critical. Key stakeholders targeted for POE collection include designers, facilities and residential life personnel, and occupants.

The data to be collected from designers includes design (plans and specifications), and finalized LEED documentation (baseline and design case documentation calculations/assumptions). Design documents provide the basis and assumptions for the design and detailed data about incorporated features. LEED documentation provides the baseline (non-sustainable) and design (sustainable) cases for comparison with actual data and benchmarking.

Facilities management (FM) personnel provide actual consumption data through metering/billing information of water and energy, plus feedback via a face-to-face survey. The survey is often useful not only to understand if a building has met design intent in practice, but also to highlight key areas of concern.

Residential life personnel are important in a dormitory because they document student number, gender split, operational days, and any complaints or concerns reported by occupants. In comparing actual consumption data to submitted LEED credits, previous data are fundamental to develop accurate benchmarking metrics.

Occupant feedback provides invaluable information on the human interaction with the dormitory. Occupants can shed light on issues related to daily use of the dormitory (i.e. faulty or hard to understand controls and thermostats, poor ventilation, leaky building envelopes, and thermal comfort), which can further be analysed by actual measurements (Cicelsky et al., 2009, Stevenson and Leaman, 2010, Gram-Hanssen, 2010, Streimikiene and Volochovic, 2011, Sterling et al., 2013). Occupants are the least used resource in POEs as the acquisition of information is often time-consuming; however, their feedback is considered critical by the authors in understanding sustainability in practice of the analyzed buildings.

3. INDICATORS ADOPTED IN EXISTING LITERATURE

LEED, BREEAM, CASBEE, LBC, and Green Globes are the most adopted rating systems. Of these only LBC is based on actual post occupancy performance, whereas the others do not mandate any POEs. LEED, BREEAM, Green Globes and CASBEE, which adopt a point scale for design and construction decisions, place the highest importance on energy efficiency (at 32%, 19%, 38% and 20% respectively), but do not mandate occupant feedback.

A review of previous sustainability rating systems shows that the design categories holding the highest importance are generally related to the behaviours and perceptions of occupants. In fact, summing together the paramenters which can be affected by occupants' behaviours and perceptions we found an overall weight of 55%, 40%, 66.5% and 42.5% on outcomes in LEED, BREEAM, Green Globes and CASBEE respectively.

In a recent study comparing responses of 42,700 occupants in mechanically ventilated buildings, over 40% were dissatisfied with their thermal comfort (Brager and Baker, 2009). This resulted in less than 11% of studied buildings meeting ASHRAE standard 55, which defines the range of indoor thermal environmental conditions acceptable to at least 80% of occupants. Major complaints were related to discomfort with temperature, lack of thermal control over their environment and unresponsive heating ventilation and air conditioning (HVAC) equipment.

Researchers have hence shown that occupants' behaviours and perceptions of the indoor environment have a large impact on sustainability in practice (Leaman and Stevenson, 2010). If occupants are provided more control and knowledge over their environment, there is a higher chance of sustainable behaviours in practice (Stevenson and Leaman, 2010). Others found that it is possible to lower energy consumption by providing feedback mechanisms and educating the occupants (Brown and Cole, 2009, Stevenson and Leaman, 2010, Streimikiene and Volochovic, 2011, Zalejska-Jonsson, 2012, Sterling et al., 2013).

FM personnel are also instrumental in guaranteeing sustainability goals are met in practice. FM personnel can ensure sustainability through on-going commissioning and routine maintenance, which allow minimization of energy consumption and ensure occupant thermal comfort. For example, manipulation of HVAC equipment start-stop times can provide savings in the range of 30-60% in energy consumption (Mathews et.al, 2001, Nguyen and Aiello, 2013). AI systems can also reduce energy consumption, through the collection of occupant behaviour to calibrate HVAC equipment. Many systems of BEMS or BACS have shown capabilities to create comfortable indoor conditions, while reducing wasteful energy consumption (Klein et. al, 2012, Yang and Wang, 2013, Nguyen and Aiello, 2013).

Considering the results of this literature review, it was clear to the authors that a comprehensive POE indicator framework needs to contain varied parameters: both physical building components and technologies, and human consumption behaviour and interaction with designed building systems. This is because if sustainability goals are to be satisfied, it is important to test how occupants interact within the buildings to ensure design expectations are satisfied.

4. RESULTS AND DISCUSSION

4.1 Selected POE indicator framework and data collection methods

Based on the review of various rating systems and published research discussed above, a series of POE indicators were selected. The four criteria followed in the selection of the POE framework have been the ability to check and support a reduction of energy and water consumption, a promotion of sustainable occupant behaviours and an assurance of occupants' thermal comfort (mainly considering temperature and humidity).

The selected POE indicators are: (1) water, (2) electricity and (3) gas consumption, (4) on-site renewable energy generation and use, (5) building systems commissioning, (6) monitoring of indoor air temperature and humidity, (7) occupant satisfaction with controllability of systems-temperature and humidity, (8) building controls ease of use, (9) routine preventative maintenance for HVAC systems and building enclosure, (10) education efforts by HE owners to promote sustainable occupant behaviours, and (11) optimization of management systems (BACS, BEMS and AI). The collection of data for indicator 11 is reliant on whether the building has implemented such advanced systems. Table 1 and 2 outlines selected POE indicators requiring quantitative and qualitative data collection methods respectively, together with researched authors supporting the specific indicator and key stakeholders to collect data from.

Indicators 1-6, 9 and 11 require the involvement of designers and FM personnel to gather actual data. Indicators 1-4 may be collected through meter readings and billing data. Data from indicators 1-4 can be used to compare actual values to finalized LEED documentation from designers, informing them if their design assumptions are valid. For example, this information can highlight monthly trends in consumption and aide in forecasting resource needs. Furthermore this information can be used to stabilize consumption loads resulting in lower utility bills and contracts. It can also help in the development of course correction measures by designers and FM personnel.

Indicator 5 provides insight into the commissioning process and any HVAC problems, which may have translated into the operational phase of the dormitory. Commissioning information available through the designers and FM personnel sheds light on actual energy consumption values experienced and potential issues with indoor air quality (temperature and humidity).

Indicator 6 focuses on indoor temperature and humidity tracking and measurement, to ensure occupants are satisfied with their indoor air conditions. It may be collected through BACS if adopted or actual field measurements. Indicator 6 data can be compared to standard ASHRAE 55 (or any other related standards adopted in the country), checking validity of the standard in practice and whether course correction measures are required.

Indicator 9 ensures dormitory envelope and HVAC systems are performing as intended. For example if window sensors have been incorporated to shut off HVAC systems when windows are open, this indicator can ensure such design features are actually delivering on their intended outcomes.

Indicator 10 requires the active involvement of residential life personnel to inform occupants of sustainable behaviours. Indicator 10 can be implemented through monthly workshops, informational flyers and emails on sustainable behaviours, which can be adopted to minimize consumption and promote sustainability in practice. An example is turning of the faucet while brushing teeth, and closing windows when HVAC equipment is turned on. Such minor educational efforts increase sustainability awareness and push the sustainability agenda into the forefront of issues on campus. Often comments and concerns are raised to residential life personnel first, followed by the involvement of FM personnel. Therefore collecting data from residential life personnel also allows triangulation of data between FM personnel, and occupants.

Indicator 11 addresses the customization of BACS, BEMS and AI in tracking, measuring and reducing energy consumption. Manipulation of HVAC start-stop times along with space utilization programming can be done through these systems, to minimize energy consumption and model occupant behaviour. This indicator can highlight whether these systems are being manipulated or customized. Often times when these systems are not customized they may result in wasteful consumption.

Table 1. POE Indicators requiring quantitative data collection methods

Selected POE indicator	Researched authors supporting indicator	Data collection method	Key stakeholders for data collection
(1, 2, 3) Building electricity, water and gas consumption	LEED, BREEAM, CASBEE, LBC, Green Globes Augenbroe & Park, 2005 Fowler et al., 2005 Gillespie et al., 2006 Woods, 2008	Metering/Billing Data (Monthly/Quarterly)	Designers and Facilities Management (FM) Personnel
(4) On-site renewable energy generation	LEED, BREEAM, CASBEE, LBC, Green Globes	Metering/Billing Data (Monthly/Quarterly)	
(5) Building systems commissioning	LEED, BREEAM, CASBEE, LBC, Green Globes Fowler et al., 2005 Yang & Yao, 2010	Commissioning Process Documentation	
(6) Monitoring of indoor air temperature and humidity	Augenbroe and Park, 2005 Fowler et al., 2005 Warren & Taylor, 2008 Choi et al., 2012	Building Automation Controls (BACs) Readings or Actual Measurements	FM Personnel
(9) Routine preventative maintenance program for HVAC systems and building enclosure.	Mathews et al., 2001 Fowler et al., 2005 Yang & Yao, 2010 Nguyen & Aiello, 2013	Process Documentation	
(11) Use of building automation control systems (BACS), Building Energy Management Systems (BEMS), and Artificial Intelligence (AI) to reduce energy consumption.	Mathews et al., 2001 Thomas & Rao 2009 Martani et al., 2012 Klein et al., 2012 Yang & Wang, 2013 Nguyen & Aiello, 2013	Survey of facilities management and BACS, BEMS, and AI System Manipulation Experiments. (Quantitative and Qualitative)	

Indicators 7, 8 and 10, may be collected from occupants, through incentivized online surveys and focus group interviews. Depending on the feedback if problem areas are identified, further research may be warranted to fix problems. Occupant feedback often highlights areas of concern FM and residential life personnel are not aware of (i.e. dissatisfaction with level of control over temperature, frustration with low flow fixtures, and efforts to circumvent sustainability features). User surveys can provide insight about design features, highlighting what should be implemented to maximize sustainable behaviours in practice and what should be avoided in future designs.

Table 2. POE Indicators requiring qualitative data collection methods

Selected POE indicator	Researched authors supporting indicator	Data collection method	Key stakeholders for data collection
(7) Occupant satisfaction with the controllability of systems-temperature and humidity	Zagreus et al., 2004 Lützkendorf & Lorenz, 2005 Turpin-Brooks & Viccars, 2006 Abbaszadeh et al., 2006 Warren & Taylor, 2008 Cicelsky et al., 2009 Steemers & Yun, 2009 Gupta & Chandiwala, 2010 Stevenson & Rijal, 2010 Deuble & De Dear, 2012 Choi et al., 2012	Survey-open ended questions, yes/no questions and 7-point likert attitude scale questions.	Designers (LEED pursuits) and Occupants
(8) Building controls ease of use (lighting switches, thermostat etc.…)	Brager & Baker, 2009 Leaman & Stevenson, 2010 Guerra-Santin & Itard, 2010	Survey-open ended questions, yes/no questions and 7-point likert attitude scale questions.	Designers (LEED pursuits), Occupants, and FM Personnel
(10) End-user consumption awareness education efforts by academic institutional owner	Masoso, 2010 Brown et al., 2010 Leaman & Stevenson, 2010 Gram-Hanssen, 2010 Streimikiene & Volochovic, 2011 Zhun, 2011 Berker et al., 2011 Zalejska-Jonsson, 2012 Nguyen & Aiello, 2013 Sterling et al., 2013	Documentation of educational methods employed and Student survey	Occupants, Residential Life Personnel and FM Personnel

5. CONCLUSIONS

The lack of clarity on POE performance indicators for HE dormitories has inhibited POE practices. However POE evaluations are key in improve the 'status quo', establishing 'best practices' and 'lessons learned', also to avoid repeat mistakes. Academic institutions are in a unique position to promote sustainability, as they have the ability and responsibility to change attitudes through education and awareness programs.

It is critical that HEs equip future generations with the knowledge required to promote sustainability. The most widely adopted sustainability rating systems of buildings focus on energy, water and indoor environmental quality measures but do not mandate occupant feedback. However, published research indicates that a holistic approach should be taken in building performance evaluations. In order for sustainability goals to become a reality, feedback and daily practices of key stakeholders (occupants, FM and residential life personnel) are critical.

POEs are a powerful tool for the evaluation of building performance. The selected POE indicators and methods of data collection presented in this paper, construct a simple yet comprehensive framework easy to implement, collect and analyse. The triangulation of qualitative (feedback) and quantitative (actual consumption and design information) data through the inclusion of various stakeholders provides different perspectives, which in aggregate paint a full picture of the performance of an HE dormitory.

Data collected through the POE process can be further used to inform future design projects as well as improve current conditions of the dormitory in question. The research results presented in this paper need to be applied to a few dormitories, testing their applicability and assessing potential improvements in application.

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