UNIVERSITY OF CAMBRIDGE

Transforming construction: impact case study

Benefits to industry: improving design decision-making and fulfilment of customer needs; evidence-based innovative digital approach to Building Performance Evaluation (BPE)

Building Performance and Big Data: A triangulated approach to continuous operational improvement

The challenge to industry

Numerous built environment industry reviews have highlighted a lack of engagement with customer needs as a critical failing. The tools for conducting Building Performance Evaluation (BPE) have been available for more than three decades but despite this BPE has failed to become standard practice.

The limited adoption of BPE is partly attributed to its failure to yield useful, actionable insights. Post Occupancy Evaluation (POE) techniques typically survey a sample of a building's occupants without contextual information gleaned from the building itself. This leads to erroneous reporting and the misrepresentation of a building's true performance.

In the absence of an established feedback loop, decision-making in design and delivery remain compromised by assumption. Improved data creation and interrogation would allow an evidence-based approach and introduce a culture of context-rich learning into built environment processes.

A better approach to BPE

This study developed and tested a new approach to BPE, seeking to understand users' views on their environment within the context of that environment. This was achieved by building upon existing methodologies for Post Occupancy Evaluation (POE) for the collection of occupants' views, which were then triangulated with a series of high-resolution datasets collected from the building itself, via a network of deployed environmental sensors. The datasets were analysed through a 'double loop learning' model.

The design of a new proposed BPE approach was arrived at through lessons learned by reviewing related research on BPE to date. The approach was then tested within a case study – a leading commercial office building in London, United Kingdom. A space utilisation survey was undertaken of the subject building to inform the deployment of a sensor network. The data collected from the sensors, alongside results from a survey of occupants, was then analysed through the 'double loop learning' model.

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The solution

Based on the belief that detailed analysis of a building's performance in-use can drive better outcomes for all parties involved in the building's lifecycle, the research aimed to develop and refine a new method for analysing the in-use performance of buildings, using both subjective feedback from building users, and objective data sets from embedded sensors and equipment. The lack of an established feedback loop for the built environment provided a clear opportunity for further research. The existing body of knowledge concerning the surveying of building occupants was supplemented with a range of other performance metrics to build the contextual knowledge lacking in previous studies.

Because the aim is to help produce 'better' buildings as perceived by the occupants, the study leveraged the analysis of quantitative data in order to better understand the occupants' subjective conclusion.

A recently constructed and occupied office building, located within the city of London, was selected as the target case study. Completed in 2013, the building was designed to the latest environmental and performance requirements, achieving a Building Research Establishment Environmental Assessment Method (BREEAM) 'Outstanding' rating and reflecting best-in-class equipment, alongside a fit-out that draws from the latest thinking in workplace design. The building consequently provided an opportunity to test how effective these principles are in producing high quality workplaces.

Digital innovation

The existing Building Management System (BMS) was deemed unsuitable for data capture due to crude environmental zoning. Therefore an alternative data capture technique was sought.

Distributed, low-power sensor networks with new wireless network technology are now available on the mass-market. These facilitate the collection of rich datasets with a very low resource overhead in terms of setup, ongoing maintenance and data formatting.

A set of sensors was deployed to capture the dataset. The sensors are independent wireless battery powered sensors that can be combined to form a mesh network around a single base station. Each sensor captures data on temperature, barometric pressure, humidity, parts per million (PPM) of volatile organic compounds (VOCs), light and noise. Data is sampled at one-minute intervals and synced to an online account for viewing and download.

These sensors were selected for the following reasons:

- low power and therefore low maintenance, requiring only monthly charge cycles of a few hours
- independent wireless mesh network means the infrastructure burden is minimal
- physical design is small and unobtrusive when located on a desk, capturing the environment as perceived by the occupant
- produce high resolution datasets, with data recorded at one minute intervals
- range of environmental criteria they capture aligns with those highlighted in existing research as significant.

Double loop analysis

The datasets were analysed through a double loop learning paradigm. The objective of this was to first build context for the learning by answering the 'single loop' question: "Is the building meeting its targeted performance criteria in terms of indoor environment?"
The objective environmental capture, alongside elements of the ancillary dataset, were used to consider this question. With a clear understanding of the building's performance against its targets gained from the 'single loop' analysis, the 'double loop' question is considered: "Do the results align with occupants' views and expectations of a high quality workplace, and if not what needs to change?" The responses from the survey of occupants were analysed to answer this question, alongside comparisons between occupant responses and the findings of the single loop analysis.

Future prospects

This study has sought to develop a sustainable model for continuous BPE, which builds upon existing POE whilst also leveraging new technologies and approaches from fields such as Big Data.
It is imperative to establish context against which to analyse survey responses. Most existing POE approaches fail to do this. Modern sensor technology provides a resource efficient route to building an awareness of how the building is performing against its target criteria.

The 'double loop' approach could form the foundation for a system of continuous, automated BPE for a given building. Such a model would continually evaluate the environment against its target criteria (continuous 'single loop' analysis). A second 'loop' of analysis would be conducted regularly using planned and reactive data collected from occupants, in order to test and reappraise the building's target criteria.

Impact and benefits

BPE in all forms has failed to become embedded in the standard practices of the property industry. This failing is exacerbated when considered in light of the ratio of costs driven by capital spend on the built environment, through to business costs and outcomes brought about by that environment.

Deployment of a continuous BPE process that is resource light but drives deep learning would help to correct this.

The adoption of a fundamentally different approach to ongoing BPE poses a challenge, but the benefits that could flow are significant – more efficient organisations with happier and healthier workers, homes in which people live more comfortably, hospitals that help to heal quicker. Such an opportunity is one that building owners and occupiers would be remiss to ignore.

The Laing O'Rourke Centre for Construction Engineering and Technology, in the University of Cambridge Department of Engineering, was launched in 2011 with industry partner Laing O'Rourke to fulfil a shared vision of transforming the construction industry through innovation, education and technology. The Construction Engineering Masters (CEM) degree programme is designed to shape the next generation of industry leaders and undertake innovative research projects that deliver value to industry.

Case study

This case study is based upon a Laing O'Rourke Centre for Construction Engineering and Technology Construction Engineering Masters dissertation titled: *Building Performance & Big Data; A triangulated approach to continuous operational improvement* (2015). The research is by David Walters, Senior Projects Director, Argent LLP.

Further details

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