# Benefits of building performance evaluation for university buildings- A Systematic Literature Review

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## Abstract
Building performance evaluation (BPE) has become an increasingly important tool in ensuring that buildings perform as intended and meet the needs of occupants. BPE is a systematic process of evaluating the performance of buildings against design and operational goals, using a range of measurement, analysis, and feedback tools. This Systematic Literature Review (SLR) paper outlines the benefits of BPE for building owners, occupants, and the wider community. The article presents a qualitative synthesis of research findings. Using a systematic review approach guided by the PRISMA guidelines, we meticulously selected and scrutinised 33 relevant articles. The systematic review consolidates information from various sources to comprehend the global importance of implementing building performance evaluations of existing buildings. The search was limited to articles published between 2020 and 2024, and the search results were screened based on their relevance to the topic. The resulting articles were then analyzed for their relevance, quality, and impact. From the literature review conducted it was discovered that for building owners, BPE could help to identify areas where improvements can be made to the building's performance, leading to increased energy efficiency, reduced operating costs, and improved occupant comfort. In addition, building owners can also demonstrate their commitment to sustainability and environmental responsibility, which can enhance their reputation and attract tenants who value these qualities. For occupants, BPE can help to ensure that buildings provide a safe, healthy, and comfortable environment in which to live, work, and play. This can lead to increased productivity, reduced absenteeism, and improved overall satisfaction with the building. For the wider community, BPE can contribute to a more sustainable and resilient built environment. By reducing energy consumption and greenhouse gas emissions, BPE can help to mitigate the impacts of climate change and improve air quality.

## Keywords
Building, Environment, Greenhouse, Occupancy, Sustainability

## 1. Introduction

Poor building performance evaluation can have significant consequences for both the occupants and the environment (Lassen et al., 2021). From increased energy consumption and higher utility costs to occupant discomfort and compromised indoor air quality, the impacts of poor building performance can be far-reaching (Wu et al., 2020). In addition, buildings with subpar performance can contribute to unnecessary strain on resources and exacerbate environmental issues such as greenhouse gas emissions. It is crucial for building owners and managers to prioritize regular evaluations of building performance to identify areas for improvement and ensure the health, safety, and efficiency of the spaces they oversee (Bueno, Xavier & Broday, 2021). Moreover, to enhance building performance evaluation, it is necessary to implement a comprehensive monitoring and benchmarking system. By regularly collecting and analyzing data on energy usage, indoor air quality, and occupant comfort, building managers can identify patterns and trends that can help pinpoint areas for improvement (Li et al., 2021). Additionally, investing in smart building technologies and energy-efficient systems can have a profound impact on overall building performance (Prameswari et al., 2021). These advancements not only contribute to reduced energy consumption and cost savings but also lead to improved occupant satisfaction and well-being (Alamin, Kamaruzaman, & Kamar, 2023). Furthermore, promoting a culture of sustainability and environmental responsibility within the organization can also play a key role in enhancing building performance evaluation (Nimlyat, Salihu, & Wang, 2022). Educating occupants and staff about the importance of energy conservation, proper waste management, and eco-friendly practices can lead to a more conscientious approach to building operations and maintenance (Maslesa et al., 2018). The study is a systematic literature review (SLR) that aims to provide comprehensive information on the benefits of building performance evaluation for university buildings. By consolidating a significant volume of information from various articles, this review contributes to understanding the global context and encourages further research and applications in this area. The review seeks to increase interest in research and applications by providing insights into the benefits of building performance evaluation for university buildings. Therefore, the paper will analyze the advantages of implementing such evaluations. Prioritizing building performance evaluation and implementing proactive measures to address areas of improvement can lead to significant benefits for both occupants and the environment.

### 1.1 Research Question

To address the above problem, the following research question guided the systematic review process:

1. How does building performance evaluation influence the energy efficiency of university buildings?
2. What are the environmental benefits of implementing BPE in terms of carbon footprint reduction in university buildings?
3. What cost savings can be achieved through BPE in university buildings?
4. How does BPE affect university buildings' operational and maintenance costs over time?

## 2. Methodology

The following section outlines the methodology employed for conducting a systematic review of the benefit of implementing building performance evaluation for university buildings. The systematic review aimed to identify patterns across the benefits of building evaluation in university buildings by integrating various studies. The research approach was qualitative, aligned with the systematic review method, and adhered to the guidelines of PRISMA. The objectives were to identify, classify, and summarize research on the benefit of building performance evaluation. The search strategies resulted in 33 peer-reviewed papers used for analysis. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines checklist by Page et al. (2020), an extensive search was conducted on Scopus, Google Scholar, and Elsevier (ScienceDirect) for article extraction. The search terms included “buildings,” “energy efficiency,” “performance,” “Building performance assessment,” “air quality,” “Environmental impact,” and “Monitoring.” The initial search yielded 250 articles, with 90 removed due to duplication. A subsequent search involved screening 160 abstracts, excluding 127 papers that did not specifically address the study's objective. A total of 33 articles were retrieved, analyzed, and included in the study. The 33 articles that were retrieved underwent eligibility assessment by two reviewers, with disagreements resolved through consensus or by consulting a third reviewer. Using pre-defined keywords and refining the checklist based on a preliminary trial, the study evaluated literature related to building performance evaluation of university buildings. Data extraction was led by one author and cross-validated by another, and any discrepancies were resolved through dialogue. Inclusion and exclusion criteria were set based on PRISMA recommendations, excluding non-research articles, works in progress, and those not meeting the inclusion criteria. The search was limited to peer-reviewed journal articles published in English, and Google Scholar and Scopus were the primary databases used to retrieve information.

## 3. Findings

This section presents the findings derived from the comprehensive systematic literature review. The subsequent discussion delves into the benefit of implementing building performance evaluations of university buildings. The search encompassed various databases using the previously described keywords. Considering all the criteria employed in the Systematic Review of Literature (SRL), the study identified the evolution of studies published in this area within five years (2020-2024). Figure 1 provides a breakdown of the countries from which the reviewed articles originated. China and The United States of America emerged as the predominant contributor 14% each, showcasing substantial research output. Italy and Spain with 10% and 7% respectively. Saudi Arabia and the United Kingdom with 4% each; Australia, Brazil, Colombia, France, India, Netherlands, and Portugal with 3% each country; Cyprus, Germany, Greece’ Indonesia, Japan, South Korea, and Turkey with 2% each. Lastly, Austria, Bangladesh, Canada, Costa Rica, Denmark, Dominican Republic, and Ecuador, with 1% publication from each country. This distribution underscores the global nature of research on this subject, with China and the United States taking a prominent lead in the number of publications, followed by several other countries making notable contributions to the discourse.

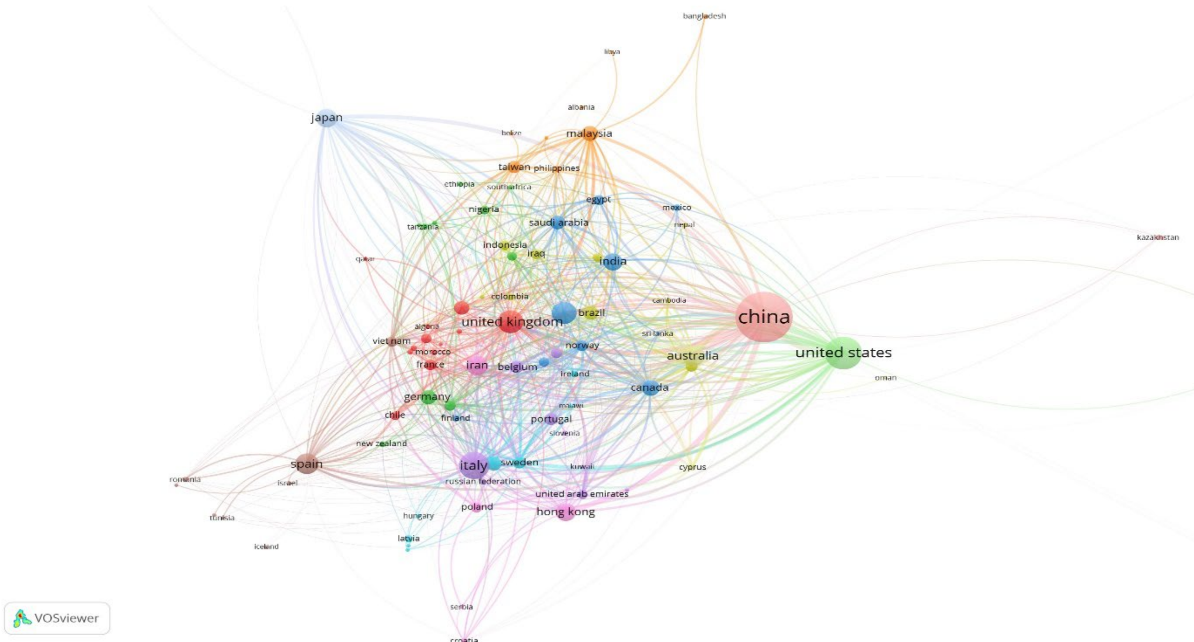


Figure 1: Bibliographic coupling document per country

Figure 2 represents the bibliometric connectivity of keywords within the articles, showcasing the interrelation of concepts across different sources and countries. This visualization offers insights into the thematic coherence and collaborative trends in research on the benefit of implementing building performance evaluation. The network of keywords demonstrates the interconnectedness of various research themes, reflecting the global collaborative efforts and shared focus among researchers. This bibliometric analysis provides a comprehensive overview of the key concepts and their relationships, contributing to a better understanding of the multidimensional aspects within the field.

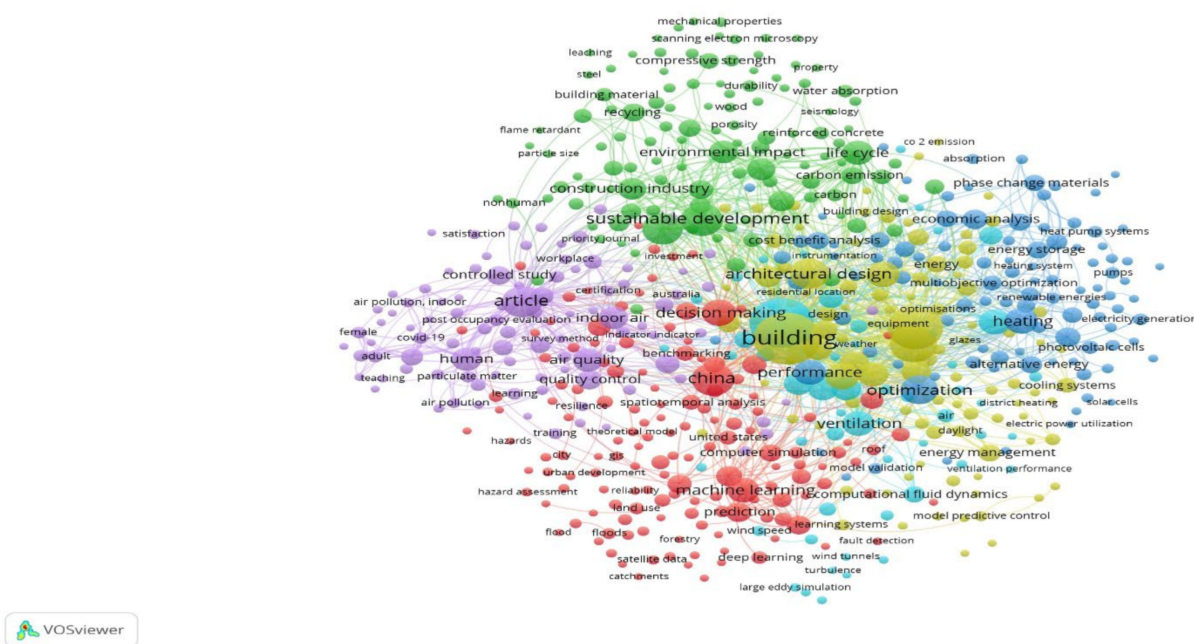


Figure 2:Bibliometric Keywords

### 3.1 Building Evaluation Performance (BEP) Or Post Occupancy Evaluation (POE)

Building Performance Evaluation (BPE) is also known as Post Occupancy Evaluation (POE), and it is the process of comprehending the actual functioning of a building. It entails the collection of on-site measurements to develop a tailored understanding of a specific building, independent of assumed inputs to an energy model (Cochran Hameen, Ken-Opurum & Son, 2020). Buildings are established to meet the needs and desires of the users and the purpose of a building is defeated if its users are not satisfied by the overall building performance (Bueno, Xavier & Broday, 2021). The performance of a building relies on various factors, including the building fabric, systems, energy usage, and occupants (Bortolini & Forcada, 2021). Therefore, building performance evaluation (BPE) identifies opportunities for improving energy efficiency in buildings. Moreover, the cause of energy inefficiencies in buildings is mainly caused by poorly insulated walls, and inefficient heating and cooling systems (Nimlyat, Salihu, & Wang, 2022). Implementing BPE will significantly reduce energy consumption and result in substantial cost savings for building owners and operators (Hou, Lai, & Edwards, 2020). According to Matse et al. (2022), a designed building should be able to perform its functions in a manner that will ensure satisfaction for its occupants and ensure effective function at all times. This theoretical paper will focus on the benefit of post-occupancy evaluation of existing buildings since most buildings, after occupancy, undergo some problems and deficiencies related to functionality and environmental aspects.

### 3.2 Promoting energy efficiency and sustainability.

Implementing energy-efficient and sustainable practices in building design, construction, and operations can have a positive impact on building performance evaluation (Balbis-Morejón, et al, 2020). These practices can reduce energy consumption, lower operating costs, and minimize environmental impact (Alamin, Kamaruzaman & Kamar, 2023). Regular evaluations of building performance can help identify areas where energy efficiency can be improved and sustainability measures can be implemented. Poor building performance evaluation can have significant negative impacts on organizations (Ceglia, et al., 2023). It can lead to increased energy consumption and operating costs, as inefficiencies and issues go unnoticed and unaddressed. Additionally, poor building performance evaluation can result in decreased occupant comfort and satisfaction, leading to potential health and productivity issues (Kamionka, 2020).

## 4. Results: benefit and insight of post-occupancy evaluation of existing buildings

Conducting a post-occupancy evaluation (POE) of existing buildings provides valuable insights into their actual performance and helps identify operational issues (Kim et al., 2020). By assessing factors such as energy consumption, indoor air quality, occupant comfort, and resource usage, organizations can better understand their buildings' performance and make informed decisions to enhance efficiency and sustainability (Castrillón-Mendoza et al., 2020). The following sections discuss the benefits of conducting POE.

### 4.1 Improved Indoor Environmental Quality

A building must provide a healthy and private environment for its occupants, making indoor environmental quality (IEQ) crucial (Ceglia et al., 2023). After occupancy, many buildings suffer from poor IEQ, affecting air quality, lighting, and thermal comfort. Facility managers and building operators should conduct POEs to enhance occupant satisfaction by addressing all IEQ aspects rather than focusing narrowly on temperature or air quality alone (Woo et al., 2021). Poor IEQ significantly impacts occupant health and productivity (Wu et al., 2020). Implementing POEs helps identify areas with poor ventilation or lighting, improving IEQ and mitigating associated health issues such as respiratory illnesses and sick building syndrome (Leccese et al., 2021).

### 4.2 Occupant Comfort and Productivity

Workspace design and operation should prioritize meeting occupants' functional and environmental needs (Akimov, Bezborodov, & Badenko, 2023). Occupant comfort encompasses factors such as temperature, lighting, and noise (Bueno, Xavier & Broday, 2021). Noise pollution from sources like malfunctioning HVAC systems or street noise can negatively affect well-being (Kaushik et al., 2020). Strategies to mitigate noise pollution should be incorporated during project planning. Optimal IEQ supports employee productivity, while compromised IEQ hinders efficiency (Al-Sabahi et al., 2022). Prioritizing employees' happiness and well-being ultimately leads to increased productivity and higher-quality outcomes for organizations (Liu et al., 2021). POEs help identify and improve areas within a facility that affect occupant comfort, such as poor acoustics or inadequate lighting.

### 4.3 Building Maintenance

Proper maintenance and repair are essential for a building to continuously meet occupants' needs and extend its lifespan (Bortolini & Forcada, 2021). One benefit of POE is that it helps facility managers identify and address areas needing repair, reducing maintenance costs (Ilevbaoje, Arum, & Omoare, 2023). Maintenance expenses can be substantial, as buildings endure various load pressures that may cause cracks and affect functionality, impacting operational capacity and user productivity (Matse et al., 2022). POE can reduce preventative and corrective maintenance costs by up to 20% (Li et al., 2021). Since 80% of energy consumption occurs during occupancy, buildings must undergo POE to enhance their lifecycle performance.

### 4.4 Increased Property Value

Energy-efficient buildings tend to have higher sales prices (Mariano-Hernández et al., 2022). Exceptional environmental performance offers advantages to occupants and investors, such as enhanced services, subsidies, financial returns, and tax benefits (Khalil & Kamoona, 2022). Labelling energy-efficient buildings raises awareness and shifts demand towards such properties (Chen et al., 2022). Therefore, POE is crucial for improving rental income and marketability.

### 4.5 Building performance evaluation for building owners

POE can lead to a 20-30% reduction in energy use for lighting, HVAC, and building envelope systems (Wang et al., 2022). It helps mitigate indoor air quality issues, optimize thermal comfort and lighting, and enhance occupant satisfaction and productivity (Liu et al., 2021). Additionally, POE contributes to environmental sustainability by reducing greenhouse gas emissions and resource consumption (Koo et al., 2018). Buildings with POE certification have higher market value and can attract tenants and investors who value sustainability and efficiency (Wang et al., 2022).

### 4.6 Building performance evaluation for occupants

A study found that occupants' perception of IEQ positively impacts their satisfaction with the building environment, which in turn enhances job satisfaction and productivity (Liu & Wang, 2022). Exposure to indoor pollutants and inadequate ventilation is associated with higher risks of respiratory and allergic symptoms (Chen et al., 2022). POEs and occupant surveys are effective tools for identifying areas for improvement and measuring interventions' effectiveness in enhancing IEQ (Nimlyat et al., 2022). Green building certification programs improve IEQ, occupant satisfaction, and building performance (Li et al., 2022).

### 4.7 Building performance evaluation for the community at large

BPE reduces energy consumption and carbon emissions, promoting environmental sustainability and benefiting the community (Hopfe & McLeod, 2021). It significantly improves IEQ, providing a healthier and more comfortable indoor environment (Wang et al., 2022). BPE also reduces building operational costs, leading to cost savings for owners and tenants, making housing and commercial spaces more affordable (Mastellone et al., 2022). Social benefits include increased occupant satisfaction, productivity, and improved social and economic well-being, contributing to more harmonious communities.

## 5. Contribution to Knowledge

Post-occupancy evaluation (POE) contributes significantly to the knowledge base within the built environment by providing empirical data on how buildings perform after they are occupied. Traditional design and construction phases often rely on theoretical models and assumptions about building performance. POE bridges the gap between expected and actual performance by offering real-world insights. This knowledge is critical for several reasons: **Validation and Improvement of Design Models**: By comparing predicted performance with actual outcomes, designers and engineers can refine their models to be more accurate and reliable, leading to better-informed design decisions in future projects. **Enhanced Understanding of Human-Environment Interaction**: POE provides detailed information on how occupants interact with their environment. This understanding can inform the design of spaces that are more attuned to human needs, improving comfort, productivity, and well-being. **Identification of Operational Issues**: POE helps in identifying inefficiencies and operational problems that might not be evident during the design phase. This includes issues related to energy consumption, indoor air quality, and maintenance needs, allowing for targeted improvements.

## 6. Implications for Educational Practice

Incorporating POE into educational practice can profoundly impact the way future architects, engineers, Quantity Surveyors and construction managers (Built environment professionals) are trained. These may include **curriculum development:** educational institutions can integrate POE methodologies into their curricula, providing students with hands-on experience in evaluating building performance. This practical knowledge is invaluable for preparing students to address real-world challenges in the built environment.

## 7. Future Directions

The future of POE holds several promising avenues for further development and application, such as integration with Smart Building Technologies: As buildings become increasingly equipped with smart technologies, POE can leverage data from IoT devices and building management systems to provide real-time performance feedback. This can lead to more dynamic and responsive building management practices. In addition, sustainability and Climate Resilience can be looked at: with growing concerns about climate change, POE can play a crucial role in assessing and enhancing the resilience of buildings. Future research can focus on how buildings perform under extreme weather conditions and how they can be adapted to mitigate climate-related risks.

## 8. Limitation

This review might be considered limited as the authors included mostly papers found discipline-specific, and only English peer-reviewed articles were used for the systematic literature review.

## 9. Conclusion

Building performance evaluation (BPE) is essential for assessing and improving energy efficiency, environmental sustainability, indoor air quality, and thermal comfort in buildings. BPE provides building owners with insights to enhance operational efficiency, reduce energy costs, improve occupant comfort, and increase property value. The literature indicates that BPE can achieve up to 30% energy savings, enhance indoor environmental quality, reduce greenhouse gas emissions, and raise property values by 5-10%. Future research should focus on integrating smart technologies and advanced data analytics, establishing global standards, and advocating for mandatory BPE to maximize these benefits. BPE is crucial for promoting sustainable and resilient built environments, benefiting both individual occupants and the broader community.

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