

Methodological contribution of building performance evaluation for facility managers of museums housed in old buildings

A contribuição metodológica da avaliação de desempenho de edifícios para facility managers de museus instalados em edifícios antigos

Contribución metodológica de la evaluación del desempeño de edificios para los facility managers de museos instalados en edificios antiguos

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Abstract

In Brazil, many museums are commonly housed in old buildings of historical value and adapted for current use. This requires specialized maintenance and oversight by the management team. Implementing Building Performance Evaluation (BPE) in active museums can be a valuable tool for enhancing the performance of the systems that comprise the building(s) under their responsibility, mainly in the use, operation and maintenance phase. Thus, this article aims to present a framework for the BPE in museums during the use, operation, and maintenance phases. A systematic literature review was conducted in Scopus and Web of Science, in addition to three interviews with managers working in museums. As a result, a framework is presented, which also encompasses the Brazilian context. As a practical implication, the aim is to support the facility managers' work regarding buildings to enhance user satisfaction and the technical performance of the built environment. By articulating theoretical frameworks and empirical analysis, this study advances the scientific understanding of BPE and offers practical guidance for improving decision-making in building management.

Key-words: Heritage; Adaptive reuse; Museums; Building in use; Performance.

Resumo

No Brasil, muitos museus são comumente abrigados em edifícios antigos de valor histórico e adaptados para o uso atual. Isso requer manutenção e supervisão especializadas da equipe de gestão. Implementar a Avaliação de Desempenho de Edifícios (ADE) em museus em operação pode ser uma ferramenta valiosa para a melhoria do desempenho dos sistemas que compõem o(s) edifício(s), principalmente na fase de uso, operação e manutenção. Assim, este artigo visa apresentar um *framework* para ADE em museus na fase de uso, operação e manutenção. Uma revisão de literatura foi conduzida no Scopus e na Web of Science, além de três entrevistas com gestores atuantes em museus. Como resultado, uma proposta de estrutura conceitual é apresentada contemplando inclusive a realidade brasileira. Como implicação prática, objetiva-se apoiar o trabalho dos *facility managers* em relação aos edifícios, tendo em vista a satisfação do usuário e o desempenho técnico do ambiente construído. Ao articular referenciais teóricos e análises empíricas, este estudo aprofunda a compreensão científica da ADE e oferece orientações práticas para melhorar a tomada de decisões na gestão predial.

Palavras-chave: Patrimônio; Reúso adaptativo; Museus; Edifícios em uso; Desempenho.

Resumen

En Brasil, numerosos museos funcionan en edificios antiguos de valor histórico que han sido adaptados para usos contemporáneos, lo que exige mantenimiento y supervisión especializados por parte de los equipos de gestión. La Evaluación del Desempeño de Edificios (EDE) se presenta como una herramienta útil para mejorar el funcionamiento de los sistemas que componen estos inmuebles, especialmente durante su fase de uso, operación y mantenimiento. Este artículo tiene como objetivo proponer un *framework* para EDE en museos en funcionamiento. La metodología incluyó una revisión bibliográfica en Scopus y Web of Science, además de entrevistas con tres gestores que trabajan en museos. El estudio resultó en una estructura conceptual que incorpora las particularidades del contexto brasileño. En términos prácticos estaba destinado mejorar la actuación de los *facility managers*, considerando tanto la satisfacción de los usuarios como el desempeño técnico del ambiente construido. Al articular marcos teóricos y análisis empírico, este estudio avanza en la comprensión científica de la EDE y ofrece orientaciones prácticas para mejorar la toma de decisiones en la gestión de edificaciones.

Palabras-clave: Patrimonio; Reutilización adaptativa; Museos; Edifícios en uso; Desempenho.

1 Introduction

The Architecture, Engineering, Construction and Operations sector is responsible for generating and managing the built environment to support human activities. Buildings in use are challenging for managers, whether due to the adopted construction system, associated cost effectiveness or user behavior, especially in old buildings, such as some museums, which have undergone adaptive reuse, the process of renovating or rehabilitating buildings to convert their use, in a context of climate change (Hamida; Hassanain, 2020; Roberts; Edwards, 2019; Apollaro; Alvim, 2017; Elay, 2001).

While the concept of building performance is rooted in the origins of architectural theory, the notion of “performance evaluation” as a formal term is relatively recent. Its conceptual foundations, however, can be traced back to Vitruvius (80 BC–15 BC), who defined architecture through *Utilitas*, *Venustas*, and *Firmitas*, corresponding respectively to functional, aesthetic, and technical performance. At the end of the 20th century, the term Building Performance Evaluation (BPE) was coined to analyze all stages of a building’s life cycle. It can also be incorporated to meet users’ needs, users satisfaction or not with the overall performance of a building (Putte; Van der Voordt; Bortel, 2023; Mustafa, 2017; Preiser, 2005).

BPE aims to assess the stages of a building’s life cycle (i.e., planning; programming; design; construction; use, operation and maintenance; and adaptive reuse). For the aforementioned stage, specifically, the multimethods approach provided by Post-Occupancy Evaluation (POE) is recommended to incorporate subjective evaluation in meeting users’ needs and expectations. Traditionally, performance can also be assessed under technical, functional and behavioral elements as well (Preiser; Rabinowitz; White, 2015; Preiser; Vischer, 2005; Park; Matheus, 2001).

One of the core premises of POE is the importance of considering users’ perceptions and satisfaction about the spaces they inhabit. This premise is justified by the fact that user behavior directly influences the built environment, potentially generating discrepancies between the performance anticipated during design and the performance actually observed through empirical measurements (Pinheiro; Roméro, 2021).

POE strategies involving technical performance and user satisfaction have been conducted in Brazilian museums in recent years. The Museum of Image and Sound of São Paulo and the Museum of Immigration of the State of São Paulo were used as case studies to measure the physical conditions of the building and accessibility. The Ema Klabin Foundation museum-house, as well as its collections, was analyzed focusing on the aspects of preventive conservation and technical performance (Lopes; Ornstein, 2018; Fu; Ornstein, 2023a; Cansado; Ornstein, 2023b).

The activities carried out in a museum are related to the main mission of researching, collecting, conserving, interpreting and exhibiting heritage, whether tangible or intangible. Brazil has approximately 3,900 museums. In addition to government policies for the sector, for example, National Museum Policy, the Statute of Museums, the National Sectoral Plan for Museums, and the National Museum Education Policy, Brazilian museums have sought to remain current by renewing their architecture, as well as their

relationship with the media and the use of emerging technologies (ICOM, 2022; Rosário da Silva; Ornstein, 2022; Cândido, 2019).

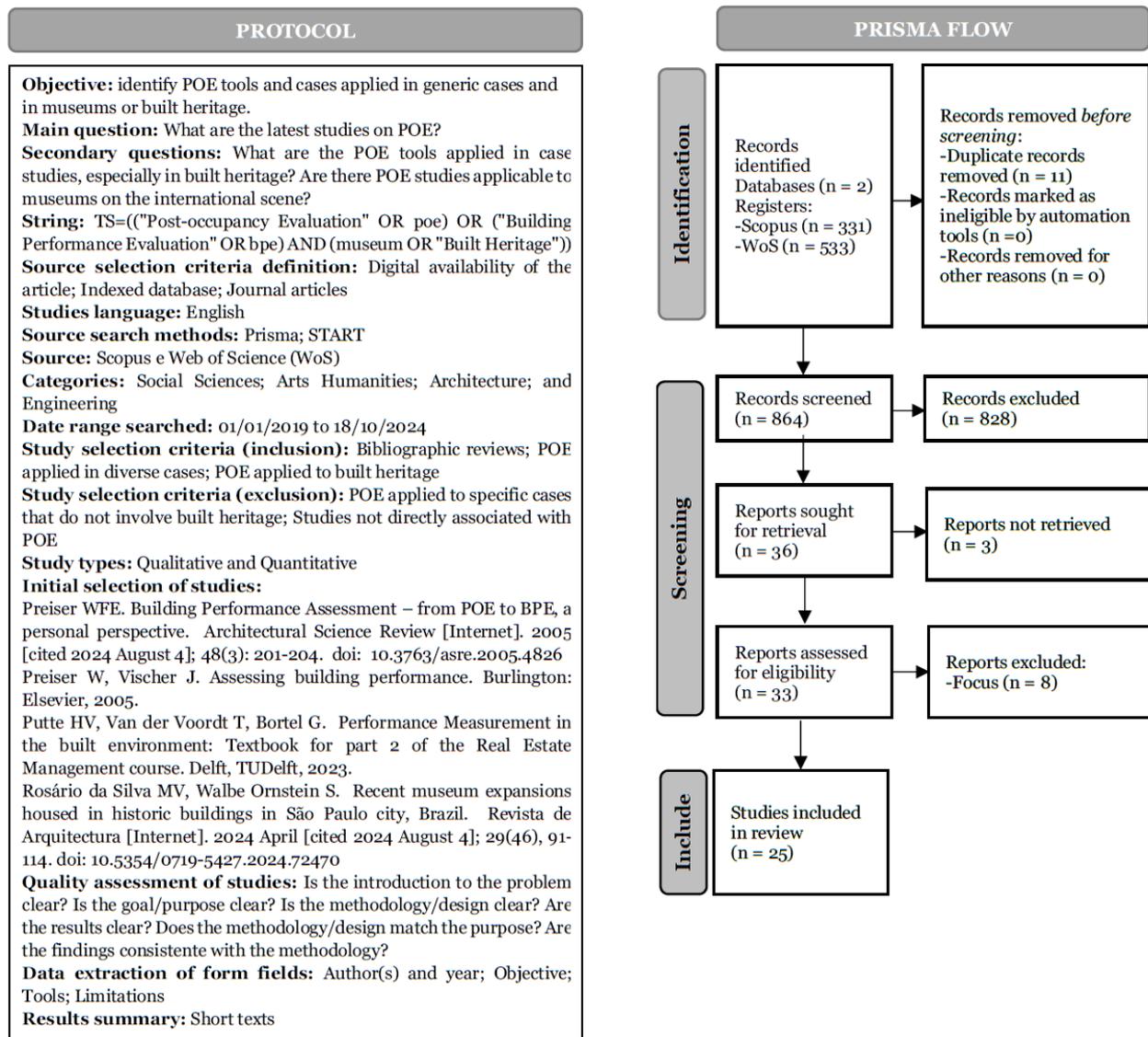
In this scenario, the following questions arise: What are the relevant tools to be applied in a Building Performance Evaluation in museums at the use, operation and maintenance stage? What are the possible emerging technologies viable to be implemented in a POE? What are the challenges faced by museum managers in Brazil regarding historic buildings? The questions aim to guide the objective of outlining a Performance Evaluation Framework for Buildings suited to the specificities of museums housed in historic buildings, including Brazilian institutions.

Despite the growing literature on BPE and POE, a research gap remains regarding their systematic application to museums housed in historic buildings, particularly during the use, operation, and maintenance stage. This study addresses this gap by proposing a BPE framework tailored to museums in old buildings. Its scientific contributions include integrating technical, functional, and behavioral performance dimensions, incorporating insights from facility managers, and highlighting the potential role of emerging technologies in supporting evidence-based decision-making. Accordingly, the overall objective of this article is to provide a structured framework to support facility managers in improving both user satisfaction and the technical performance of heritage buildings used as museums.

2 Methodological procedures

The study was initiated by a Systematic Literature Review, using the StArt (State of the Art through Systematic Review) software. A protocol was developed to conduct the stages, summarized by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Flow (Figure 1). Thus, a total of 864 articles on Building Performance Evaluation or Post-Occupancy Evaluation were tracked, resulting in 25 papers to consolidate the state of the art on the topic (Rosário da Silva; Ornstein, 2024).

Figure 1: Protocol and PRISMA Flow.



In addition to Systematic Literature Review, seminal texts by Preiser were used to consolidate the theoretical framework, as well as a recent text by der Voordt on Building Performance Evaluation. Thus, the subsections ‘Building Performance Evaluation dimensions and tools in the use, operation and maintenance stage’, ‘The State-of-the-art of Post-Occupancy Evaluation’, and ‘Post-Occupancy Evaluation and Built Heritage’ address the findings from the literature (Putte; Van der Voordt; Bortel, 2023; Preiser; Rabinowitz; White, 2015; Preiser, 2005; Preiser; Vischer, 2005).

Moreover, the understanding of the Brazilian context was based on three interviews conducted with experienced facility managers working in museums housed in old buildings in the city of São Paulo, who kindly agreed to participate in the research anonymously. These interviews were conducted between 2022 and 2023, with prior approval from the Research Ethics Committee of the Faculty of Philosophy, Languages and Literature, and Human Sciences of the University of São Paulo, CAAE:

50859621.6.0000.0138, approved on September 15th, 2021. The semi-structured interviews, developed in the context of a doctoral thesis, focused on the challenges and opportunities for facility managers in museums housed in historical and culturally relevant buildings (Rosário da Silva, 2025).

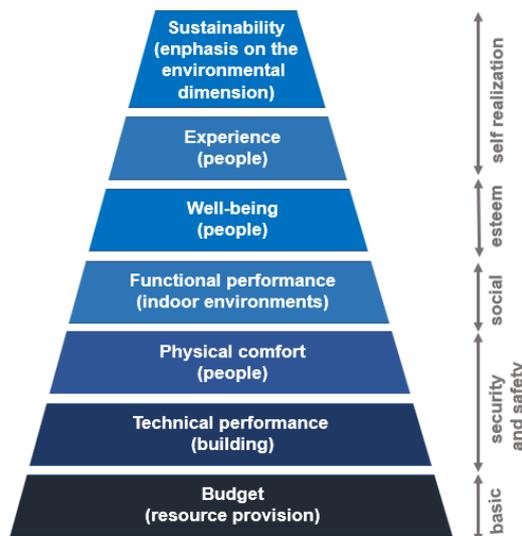
The guiding questions of the interviews were: How was the process of implementing Facility Management carried out in the museum where you work? What are the main challenges in the management of historic buildings? What improvement opportunities were identified and implemented in the building(s) that are part of the institution?

Data analysis was based on qualitative content analysis through systematic cross-comparison of the three interview transcripts, allowing for the identification of convergent themes across participants' perspectives. These convergences are presented in the subsection "Brazilian museums and facility managers: a challenge."

3 Building Performance Evaluation dimensions and tools in the use, operation and maintenance stage

Putte, Van der Voordt and Van der Bortel (2023) identified and categorized seven performance dimensions relevant to real estate performance. Figure 2 presents the seven dimensions from the perspective of a building and its users. The hierarchical form comes from the well-known Maslow's Hierarchy of Needs pyramid (1954) whose concepts are still current. The base of the pyramid consists of the provision of resources to balance the budget for the building maintenance. It is followed by the dimensions of security associated with technical performance, safety and comfort; functional performance of indoor environments; well-being and even people's happiness related to their enjoyment of public places and work environments; experience and people's satisfaction with the building; and finally, the sustainability of the building, focusing on environmental aspects, for example, low energy consumption, greenhouse gas emission inventory - taking into consideration climate change.

Figure 2: Seven dimensions of building performance.



To enable the evaluation of one or more performance dimensions, there are several tools recommended by POE, depending on the researcher's needs. However, a Systematic Literature Review identified that the User Survey via questionnaire forms was applied in approximately 80% of the published works. While interviews, walkthroughs and thermal measurements were randomly presented in approximately 40% of the selected articles (Lia; Foreseb; Bragerc, 2018).

3.1 The state-of-the-art of Post-Occupancy Evaluation

The Systematic Literature Review enabled us to identify articles exclusively focused on bibliographic reviews, multiple case studies, application of emerging technologies for data collection, and research on Post-Occupancy Evaluation in built heritage. Using a bibliometric review, Mustafa, Ani and Hussain (2022) explored POE research between 1979 and 2020, resulting in the analysis of 381 publications on the subject. It was identified that historic buildings are underexplored, mainly regarding maintaining good conditions of use. This review was limited by logical operators, for example, and, or, etc, and keyword choices for document selection.

On the other hand, in a scientometric analysis, Jiang, Wang and Shu (2022) addressed 1,351 articles between 2002 and 2021. The research points to a trend for more future empirical studies of POE in different environmental conditions and constructive types, exploring aspects of 'health and comfort' of building performance during the use, operation and maintenance stage. Due to the large number of articles, the authors used the Citespace software, declaring limitations for in-depth interpretation of some subfields.

Among the multiple case studies developed in China, environmental measurements, for example, illuminance, sound pressure, CO₂, fine particles, formaldehyde, and/or hygrothermal, and surveys via questionnaires were carried out in ten non-residential buildings, in public buildings, and green buildings. The studies carried out in non-residential and public buildings revealed deficiencies in the individual performance of each building. Research in green buildings sought results through statistical analysis via correlation (Tang; Ding; Singer, 2020; Miao; Ding, 2020; Wang; Zheng, 2020).

Some experimental studies applying emerging technologies to Post-Occupancy Evaluation were also mapped. Virtual Reality was applied to the wayfinding tool, allowing the rapid collection of behavioral data to generate guidance path data for evaluation. A total of 13,712 path samples were collected over 72 hours of activity. The Internet of Things was applied to control user comfort in real-time, mitigating problems with the central air conditioning system (Sun et al., 2024; Rasheed et al., 2024).

The Internet of Things can be integrated with Building Information Modeling and the Geographic Information System, constituting a digital twin for collecting, modifying, analyzing and visualizing data regarding the quality of the indoor environment. As a limitation, digital twins do not incorporate the addition of human behavior to determine its impact on building performance, requiring the researcher in the building. Considering the possibility of integrating different emerging technologies, a Digital Curation model was proposed to serve as a framework for storage, archiving, retrieval and data use (Tripathi; Froese; Mallory-Hill, 2023; Patlakas; Musso; Larkham, 2021).

3.2 Post-Occupancy Evaluation and Built Heritage

An evaluation of cultural satisfaction performance in historic buildings with Adaptive Reuse was conducted. In addition to a survey of users, data were collected on the date of construction, information about the architect and builder, uses of the building over time, historical events related to the building, and the relationship of the building with the neighborhood and the society as general (Islamoglu; Yenice, 2022). Another studies – in a similar vein – points out that preservation standards should be analyzed together with thermal comfort, providing heritage preservation, conservation of artifacts, and user satisfaction from the intervention process (Jia et al., 2023; Martinez-Molina; Williamson; Dupont, 2022).

Some case studies on historic buildings with Adaptive Reuse have been conducted, addressing different uses, such as educational, hotels, and museums. A study conducted in schools adopted six key elements: inheritance of the historical context; improvement in environmental quality; completion of infrastructure; achievement of educational goals; participation of children in activities; and sustainable development. The research indicates that experts focus more on the perspective of historical and cultural heritage, this focus on the authenticity of buildings, preservation of historical value and educational significance of cultural heritage. In this case, children value more intuitive experience of space, this interactivity and interest in spaces, accessibility and safety. The study's limitation lies in the need to develop procedures tailored to the varying levels of children's understanding (Xiao; Yoon, 2024).

Adaptive Reuse for conversion in hotels was also the subject of study in Iran and Jordan. The studies explored the main architectural factors in adapted buildings by administering questionnaires to approximately 300 guests per survey, which were analyzed using factor analysis or multiple regression. The focus was on 'physical feasibility' and 'assessment of the building's functional potential', followed by 'Adaptive Reuse design' and 'quality of building conservation'. The limitation highlighted in the research refers to the restriction to boutique hotels (Farashah et al., 2023).

Finally, two studies on Post-Occupancy Evaluation in museums were also selected. One was an archaeological museum in Jordan and the Mugla Museum – a former prison building. In the archaeological museum, questionnaires were applied to identify user satisfaction with technical, functional and behavioral elements. In addition, other complementary qualitative methods were used to determine the quality of the design. In the Mugla Museum, archive research, plan analysis, observations and interviews were carried out. The functional and perceptual performance results according to a questionnaire scale value was 'neutral' and the technical performance was 'good'. It is worth noting that the users' satisfaction may differ from the measurements of the functional and technical performance of the building (Khasawneh, 2024; Erdona; Polatoglu, 2021).

In summary, the performance assessment of old buildings that house museums presents specificities that must be considered, for example, long useful life, respect for the historical and/or cultural values attributed and environments with more rigorous control of climatic parameters.

4 Brazilian museums and facility managers: a challenge

A Facility Manager is the professional responsible, among various tasks, for the operation, maintenance, improvement and adaptation of the building. These professionals are often interested in the technical dimension. In the case of museums, maintenance can cause damage to works of art, for example, interruptions in the Heating, Ventilation and Air Conditioning System in exhibition rooms or storage areas, or even be incorporated into the conservation process of assets integrated into the built heritage, for example, tile mosaics (Martins, 2024; Tannor; Appau; Attakora-Amaniampong, 2023; Pietrafesa et al., 2020).

This expertise is essential for maintaining and adapting buildings that house museums. The interviewees reported that the challenge of managing built environments is directly related to operating in historical buildings, where any intervention requires official authorization, impacting both timelines and solutions. Furthermore, maintaining stable temperature and humidity levels is crucial for the preservation of artworks. Electrical systems, humidity control, and limited time slots for maintenance - due to the museum's constant public access - also represent significant constraints.

Regarding the organizational structure, some museums operate with separate coordinations for infrastructure and security, while others consolidate these functions under a single Facilities Management department, responsible for maintenance, security, cleaning, construction works, and, in some cases, exhibition design. The implementation of Facility Management should begin with a comprehensive mapping of the building's infrastructure.

In terms of improvements, notable initiatives include the replacement of chillers, modernization of Heating, Ventilating and Air Conditioning automation systems, structural reinforcement of the roof, and the construction of a new retail store. The effective implementation of a maintenance plan based on procedures is also considered a major achievement, enabling accurate diagnostics, resource mobilization, and strategic planning for interventions. Even when maintenance is not formally classified as restoration, it is always carried out with the same level of care, balancing technical, heritage, and cultural challenges.

Performance evaluation is important, whether in the case of public or private buildings, to define a master intervention plan. In public buildings, similar to many Brazilian university museums with a lack of budget, there is a tendency for more significant degradation, resulting in the need for more frequent and/or costly corrective maintenance activities. Especially in a context of climate change with intensified natural hazards, for example, floods, severe storms, heat waves, droughts and/or landslides (Levéfre; Sabbioni, 2018).

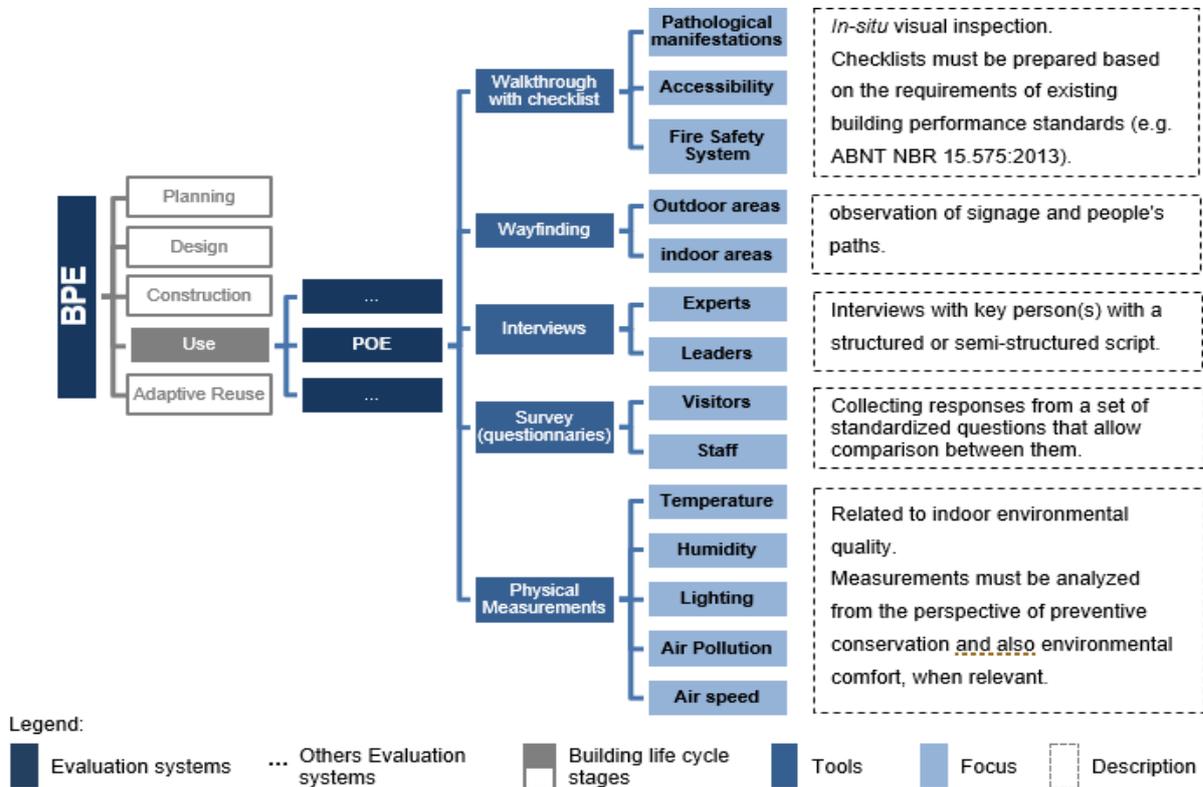
4.1 Building Performance Evaluation's contribution to museum facility managers

Figure 3 presents the conceptual framework of Building Performance Evaluation applied to old buildings in the use, operation and maintenance stage that house museums. This framework was developed based on the findings of the Systematic Literature Review and aligned with the needs expressed by managers during the interviews conducted.

Thus, the walkthrough with checklist, interviews and physical measurements support the evaluation of technical and functional performance. The survey via questionnaires and

wayfinding support the evaluation of behavioral performance/experience corroborating the research conducted in the archaeological museum of Jordan. The tools were applied differently among the studies mapped in the state of the art and they prove to be relevant and complementary for the proposed comprehensive analysis (Khasawneh, 2024).

Figure 3: Framework for PBE of museum in operation.



In this way, POE tools encompass activities conducted by specialists (walkthroughs, wayfinding, and physical measurements) as well as the collection of user information and perceptions (surveys and interviews). These tools address safety issues for people (structural performance, accessibility to indoor and outdoor areas, and fire safety systems) and for collections (measurements of temperature, humidity, lighting, air pollution, and air speed).

The qualitative–quantitative approach not only enables data analysis and comparison with the literature but also emphasizes the subjectivity of the different stakeholders — including visitors, experts, leaders, and staff.

When considering the seven dimensions of performance, a lack of well-being and sustainability (dimensions closest to the top of the pyramid – Figure 1) were identified in the studies. These are topics that can be absorbed transversally in the application of the tools listed in the Figure 2, using the Sustainable Development Goals as requirements. As indicated by interviews with facility managers, the challenge is related to the processing of interventions with heritage agencies and the degradation status of the building's systems.

Thus, data on the history of the building and the plan analysis are of utmost importance to understand the historic building under study. Likewise, a critical analysis of the aspects of heritage preservation versus user satisfaction should be investigated, discussed and considered. Emerging technologies have the potential to assist data collection for evaluation, as do Internet of Things sensors for capturing physical measurement data, Building information Modelling and Geographic Information System for storing and visualizing graphic and non-graphic data and Virtual Reality for simulating user behavior in wayfinding analysis (Rasheed et al., 2024; Sun et al., 2024; Tripathi; Froese; Mallory-Hill, 2023; Islamoglu; Yenice, 2022; Martinez-Molina; Wiliamson; Dupont, 2022; Erdogan; Polatoglu, 2021).

Among the barriers to implementing technologies in the Brazilian context is the maturity of the development stage of the solutions. However, future studies recommend incorporating emerging technologies to assist in the collection and analysis of data generated in buildings, in addition to the dissemination of extensive public research, including children, adolescents and adults, in a museum environment (Rosário da Silva et al., 2024).

Although emerging technologies such as digital platforms, IoT, and augmented reality offer significant potential to enhance museum operations and visitor engagement, their adoption in Brazil remains limited by structural and policy-related constraints. Investment in technological innovation within heritage and facility management is uneven and largely concentrated in commercial contexts. At the policy level, existing frameworks, including the Brazilian Statute of Museums, the Política Nacional de Museus, and the Brazilian Museum System, emphasize preservation, access, and participatory governance but provide limited guidance or incentives for the systematic integration of emerging technologies.

5 Final considerations

Finally, in old buildings housing museums, the PBE structure, at the use, operation and maintenance stage, was defined from a Systematic Literature Review to identify the state-of-the-art around the world, and interviews were conducted with experienced facility managers working in museums in Brazil. Systematic Literature Review provided the tools usually applied, through Post-Occupancy Evaluation, to historic buildings and/or museums; while the interviews presented a summary of the challenges present in the management of museums housed in old buildings.

The main contributions are: (1) the proposal of a framework for applying Building Performance Evaluation in the use, operation, and maintenance stage, content tools like walkthrough with checklist, wayfinding, interviews, survey via questionnaires, and physical measurements of the temperature, humidity, lighting, air pollution, and air speed - measures to safeguard the collection and ensure human comfort; (2) mapping emerging technologies with the potential to contribute to applying of Post-Occupancy Evaluations to support diagnoses and recommendations for improving building performance; (3) Highlight the main challenges for facility managers working in museums housed in old buildings.

This study is limited by the small number of interviews (n = 3), the focus on Brazilian museums, and constraints inherent to the Systematic Literature Review. Future research should validate the proposed framework through case studies in different contexts, as well as explore the gradual incorporation of emerging technologies to support old building performance evaluation.

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