Journal of Cultural Heritage xxx (2016) xxx–xxx

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com/en

Review

Multidisciplinary risk-based analysis for supporting the decision making process on conservation, energy efficiency, and human comfort in museum buildings

Elena Lucchi *

Politecnico di Milano, Via Bonardi 9, 20133 Milano, Italy

ARTICLE INFO

Article history:
Received 27 February 2016
Accepted 1st June 2016
Available online xxx

Keywords:
Museum buildings
Preventive conservation
Human comfort
Energy efficiency
Risk-assessment model

ABSTRACT

The paper presents a method for assessing the environmental and the energy performance of museum buildings, demonstrating that conservation, human comfort, and energy efficiency are mutually compatible when based on rational planning, interdisciplinary cooperation, and extensive knowledge of museum buildings and collections. The operative tool assists the decision makers in optimizing planning actions during the energy and environmental retrofit, maintenance and management, to: (i) extend the lifetime of heritage; (ii) identify the conservative risks and quantify the factors responsible of damage phenomena; (iii) improve the building performance; (iv) minimize consumptions and costs, (v) establish appropriate procedures and policies; and (vi) program the retrofit. To merge different aspects, we use the SOBANE strategy (screening, observation, analysis, expertize) to organize efficiently, economically, and durably the risk management and, consequently, the retrofit actions. The methodology has been structured in four levels of investigation: (i) "screening" for assessing the museum performance; (ii) "observation" for detecting causative factors, present and potential risks; (iii) "analysis" for quantifying the environmental and energy risks with detailed investigations and long-term measurements; and (vi) "expertize" to provide guidelines for implementing and prioritizing appropriate solutions to solve specific problems related to prevention, human comfort, and energy efficiency. This methodology neither meant to be exhaustive or definitive, but simply aims to serve as a reference for technicians and conservators, who require clear and easy procedures and applicable solutions.

1. Introduction

Nowadays, the museum is a complex building characterized by different purposes [98]. Alongside the traditional functions (preservation, study, and exhibition), new activities and spaces for education and tourist entertainment arise (e.g. conference rooms, laboratories, bookshops, libraries, play zones, restaurants, cafeterias, and shops). In many cases, to reach a balance between conservation, occupants' comfort, and energy efficiency it is very hard because these objectives involve opposite needs [1–3]. Care of the collection and the building requires a strict control of light, air temperature, relative humidity, and pollutants, which often imposes the use lighting and air-conditioning systems with consequently high-energy consumptions. On the contrary, free access, and complex activities generate microclimatic instability and indoor pollutants. Therefore, it becomes necessary to achieve sustainable and cost-effective interventions by reducing the energy demands and the operative costs, without jeopardizing the safeguard and the human comfort. This is one of the most important challenges of the museum buildings.

The studies on environmental and energy quality of museum buildings are rather recent. In the first case, the research focuses mainly on preventive conservation of historic buildings and art collections, aiming at investigating the environmental parameters that cause damage to the heritage. The early literature on preventive conservation in museum building was characterized by the progressive integration of science into conservation activities, providing instructions to avoid moisture, insects, and pest problems through a careful planning of the indoor environment [4–6]. The idea of "heritage protection" changes in the last century (1930s and 1940s), thanks to the collaboration between conservators and scientists [5–7]. It has gradually abandoned the traditional logic of "restoration", where the effects of decay are repaired by invasive interventions [8], to adopt the idea of "prevention" [9,10]. The

* Present address: EURAC Research, Viale Druso 1, 39100, Bolzano, Italy.
E-mail address: elena.lucchi@polimi.it

http://dx.doi.org/10.1016/j.culher.2016.06.001
1296-2074/

progressive integration between science and conservation included different methodologies, oriented to preserve the historical pieces themselves, and against the passage of time and environmental factors [6,11]. Plenderlith [12] made a systematic exploration of deterioration mechanisms, demonstrating the possibilities to minimize the physical harms on antiquities and artworks mainly by recognizing the causes of damage. These studies had a remarkable development in the sixties, in response to the emergencies for the safeguard of the collection caused by floods and other catastrophic events in several European museums and city centers. These theories introduced the items of "planned conservation" [5,13–15] and "environmental restoration" [16] for preserving buildings and collections, particularly focusing on the context surrounding the heritage. In the following decades, international organizations such as the International Council of Museums (ICOM) and the International Centre for the Study of Preservation and Restoration of Cultural Property (ICCROM) played a crucial role for establishing optimal light and hygrothermal levels to reduce damage on the pieces of art [17,18]. These standards shown the central role played by the environmental control for reducing damage, losses, or even destruction of the exhibits [19]. The discipline of "preventive conservation" in museum buildings has been founded from these studies [6,20,21], as "[. . .] non-interventive actions taken to prevent damage and minimize deterioration of a museum object" [3]. Thomson [22] developed the basis of this discipline in a systematic way, organizing standards, rules, and experimentations. The consciousness of the importance of the "environmental impact" on heritage, introduces a broad debate on the "safe" levels of light [23–26], climate [21,23,27,28], and concentration of pollutants [29,30]. Initially, general guidelines did not consider any interrelationship among them [30–34] but, later, Camuffo [2] demonstrated the cumulative effects of these parameters. His work outlined national and international standards and guidelines on preventive conservation of museum collections, considering also human comfort [18,19,35–40]. Initially, the publications concerned principally the criteria and the variables for guaranteeing the visual comfort and the preservation of the photochemical damage [18,23,24,35] but, later, the Commission internationale de l'éclairage (CIE) [35] recommended to maintain an adequate comfort level for users, reducing the "annual energy exposure" (AEE) to light. The first studies on thermal and hygrometric comfort considered mainly the use of air-conditioning systems in museum buildings [1,41] or exhibits [42]. Furthermore, the benefits of bioclimatic and passive measures for the environmental control of museum rooms have been investigated [43,44]. Particularly, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) [41] delineated different protection levels related to the sensitivity and the fragility of artifacts, introducing four categories of "museum climate" with different indoor conditions and exposure durations. This theory introduced the concept of "adaptive comfort" as a balance between conservative and comfort requirements. It also changes the perspective of preventive conservation, remarking the importance of the environmental design and the management procedures. In parallel, several cultural institutions drafted guidelines and policies for the environmental management, departing from practical experiences and adapting the standards to the complexity and the variety of the museum heritage [34,45–48]. The actions ranged from building maintenance, control of staff practices, climate control, and legislation. Moreover, the works on olfactory and acoustic comfort are not specific for the museums.

Normally, these studies are not connected to the researches on energy audit or energy efficiency in existing buildings. Only a specific research observed the energy quality of museums [20]. More recently, the European legislation on energy efficiency of buildings picked up this topic, boosting the reduction of CO_2 emissions, the rise of the share of renewable sources, [49,50], and the retrofitting of existing buildings [51]. The directives introduced only the broad principles for the intervention, leaving to the local legislation the definition of policies dealing with national studies on architectural restoration. In general, the museums placed in "listed buildings" are excluded from the application of energy constrains when they cause "significant" changes in the appearance or cultural value. On the contrary, the museums sited in "historical buildings" or new museums are entirely subject to this scheme and must have performance very similar.

The European standards also defined the energy audit [52], clarifying the competences of the energy auditor and developing a qualification scheme [53]. In parallel, the literature attempts to define a shared methodology for the energy audit of existing buildings. The first studies concerned the building management [20,54], and the efficiency of lighting [24,26] and air-conditioning [41]. Only later, specific works on the whole building has been developed [54–56]. None of these books were devoted specifically to museums or historic buildings, but the methodology developed by Thumann and Jounger [56] organized in an ordinate way this knowledge and was adopted widely in the reference literature [57–59]. More recently, several environmental protocols have been developed [60–62]. They considered also the energy performance evaluation, but were not specifically designed for museum buildings. Moreover, the European Committee CEN/TC 346 [45] provided specific standards for protecting the collections, controlling the environmental variables, and implementing the energy efficiency (also in this case not specifically for museum buildings, but only for historic buildings). Finally, very recent, several case studies tested different thermal control strategies for reducing the energy consumption in museums [63–67]. Ascione et al. [64] and Kramer et al. [67] confirmed the validity of this approach, obtaining an energy saving from 40% to 77%. These researches regard the thermal comfort, not light, air quality, and pests' management.

The analysis of the scientific literature shows two peculiar sectors of the research on environmental and energy quality in museum buildings. On the one hand, the environmental evaluation is related to preventive conservation and human comfort, in order to balance the opposite requirements of preservation and enhancement of the heritage. On the other hand, the energy assessment schemes are not specific for the museum.

Procedures, methods, and tools that match the environmental and energy performance (EEP) assessment in museum buildings lack, mainly due to the complexity and the specificity of the studies. On the contrary, the literature provides several principles and criteria that can be used as a starting point for the definition of a cross-disciplinary approach on museum buildings and collections. Following, the key elements considered by scientific works for the EEP assessment of museums are reported, highlighting also the methods and the tools already developed (Fig. 1).

2. Research aims

The paper presents a method for the EEP assessment of museum buildings, combining methodologies and criteria developed in the fields of preventive conservation, human comfort, and energy audit. This method aims at supporting museum authorities (public administrations, directors, registrars, conservators, curators, owners, guardians, and technicians) in a systematic definition of critical issues and solutions, to:

- extend the lifetime of heritage;
- identify the conservative risks;
- quantify the factors responsible of damage phenomena;
- select the most appropriate solutions to improve the energy and the environmental performance;

Please cite this article in press as: E. Lucchi, Multidisciplinary risk-based analysis for supporting the decision making process on conservation, energy efficiency, and human comfort in museum buildings, Journal of Cultural Heritage (2016), http://dx.doi.org/10.1016/j.culher.2016.06.001