Frontiers of Architectural Research (2018) 7, 367–382

Available online at www.sciencedirect.com

Frontiers of Architectural Research

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RESEARCH ARTICLE

The application of building performance simulation in the writing of architectural history: Analysing climatic design in 1960s Israel

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Received 18 July 2017; received in revised form 2 June 2018; accepted 10 June 2018

KEYWORDS
Architectural history;
Building performance simulation;
Thermal performance;
Israeli modern architecture;
Building climatology

Abstract
This article presents a methodology for the integration of building performance simulation (BPS) into the writing of architectural history. While BPS tools have been developed mainly for design purposes, their current maturity enables to reliably apply them in simulating the performance of past buildings, even when these buildings have been significantly modified or demolished. The possibility to virtually reconstruct the performance of past buildings can help us to overcome the existing knowledge gap in the understanding of the role played by building performance and building performance research through the history of architecture and can therefore promote the intelligent and successful application of environmental features in contemporary architecture. The potential of the proposed methodology is presented here using a historical case study from 1960s Israel (a university building in Tel Aviv), in which climatic considerations were an explicit part of the entire design process. The original thermal performance of the building was analysed by employing the EnergyPlus simulation engine, and the simulation results were used for evaluating the climatic impact of certain design decisions, comparing them with the proclaimed design goals and the original intentions of the architects.

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☆Peer review under responsibility of Southeast University

https://doi.org/10.1016/j.foar.2018.06.003

1. Introduction: writing building performance into architectural history

In the writing of architectural history, building performance has traditionally occupied a relatively marginal position. Writers on architecture, especially in modern times, have tended to emphasize the aesthetical, social, cultural, and technological aspects of design rather than its performative outcomes. One famous exception is Reyner Banham's seminal work *The Architecture of the Well-Tempered Environment* (originally published in 1969 with a second, revised edition published in 1984), which focused on the evolution of environmental technologies in modern buildings. The position of the historian enabled Banham to explore how knowledge and innovations in building controls were disseminated, adopted, manipulated, or ignored by modern architects and designers and how their application affected the performance of buildings.

Despite introducing an innovative, performance-oriented approach to the writing of architectural history, Banham's research methodology remained quite conventional: his environmental analyses were based mainly on archival documents (texts, photographs, drawings) and on his subjective impressions, based on personal visits to the buildings he studied. Performance was thus assessed not by examining measurable and quantifiable criteria, but rather by following Banham's personal presumptions and judgements. One typical example was Banham's analysis of Philip Johnson's *Glass House* in New Canaan: Banham judged the house to be a 'unique example of environmental management in an extended sense' (Banham, 1984, 230), but analysed its thermal mechanisms by relying exclusively on several impressionistic conjectures based on his own reading of the structure and its surroundings, without providing even a single measurable piece of data (like indoor temperature levels) to support his claims.

Banham's book remains almost a one-of-its-kind in applying the historian's perspective to the field of building performance. Even today little is known on the ways knowledge on building performance has been used by design professionals in their actual practice, despite almost a century of scientific research into the interrelations between climate and the built environment (Lea, 1971; Tomlow, 2006; Hebbert and Mackillop, 2013). The result is a major knowledge gap with respect to the history of scientific building research and its application in modern architectural practice.

Revealing building performance's 'untold histories' can be achieved through the adoption of the historian's mode of inquiry, focusing on the reciprocal relations between building performance and architectural design. Nevertheless, and despite the time that passed since Banham's 1960s study, only a few scholars, like Denzer (2013) and Barber (2016), followed Banham's steps by writing on building performance from a historical perspective. Like Banham, they did so by applying a somewhat speculative and impressionistic research methodology for assessing the actual performance of the buildings they researched.

This article presents an alternative approach to the writing of building performance into architectural history. The proposed methodology attempts to overcome the limitations of conventional historical research methods by applying building performance simulation (BPS) tools for the generation of comprehensive datasets of performance indicators. Such indicators enable to reliably and effectively draw quantitative as well as qualitative conclusions on the intended or realised performance of buildings, unmatched by any other analytical tool available today, thus adding a novel, performance-based perspective to the common methodologies of research in architectural history.

While BPS has been already sporadically used for analysing certain performative aspects of historic buildings (see for example Laar, 2001; Cabeza et al., 2006; Balocco and Grazzini, 2009; Ryan, 2010; Aleksandrowicz and Mahdavi, 2012; Hensel et al., 2012), this has not been done from a broad historical perspective that integrates the social and cultural aspects of design through rigorous historical research, based on archival documentation and other written or oral sources. The research methodology proposed here, which harnesses the unique capabilities of BPS for broadening the historical perspective on architecture and building performance, is multi-disciplinary in nature and requires expertise in both history writing and building research. Its added value, which is the ability to reliably quantify past performance of buildings in their original state or design, has a potential for providing new insights on the relations between architectural design and building performance and the possible transformations of these relations through time.

2. The advantages of BPS-based methodology for studying historic buildings

Building performance and indoor human comfort are commonly analysed today by referring to quantifiable and measurable climatic indicators (e.g. indoor air temperature, mean radiant temperature, relative humidity, wind speed, illuminance levels, energy consumption, etc.). Historical accounts of architecture that focus on building performance should be able to use such indicators to avoid the biases and misconceptions of personal subjective impressions.

Quantifiable data on building performance can be generated in two major ways, namely empirical monitoring of buildings and numerical building performance simulation. Although monitoring of existing buildings is still the preferable way to accurately evaluate their performance, this method may prove inapplicable or inefficient in the study of the original design and functioning of historic buildings, for two main reasons. First, many historic buildings of interest may no longer exist or at least do not exist in their original form (especially when it comes to their building envelopes or HVAC systems), making the evaluation of their performance *in their original state* simply inapplicable through monitoring. Secondly, even if we are lucky enough to find a historic building preserved in its original (or near original) form, monitoring it may prove to be labour and resource intensive, relying on long-term measurements and filtering out user behaviour effects on indoor conditions, in a way that makes its integration into the workflow of conventional history writing a genuine challenge.

BPS tools are unique in the way they can be used, as a virtual controlled 'laboratory' set-up, for producing quantifiable and relatively reliable data on the performance of buildings. They are highly suitable for generating meaningful insights on the performance of historic buildings