BUILD SIMUL
https://doi.org/10.1007/s12273-024-1146-1

Perspective

Overcoming fixation: Shaping BPS to fit into design practice

Pieter de Wilde[1] (✉), Clarice Bleil de Souza[2]

1. Division of Energy and Building Design, Lund University, Sweden
2. Welsh School of Architecture, Cardiff University, UK

Received: 21 April 2024; **Revised**: 12 May 2024; **Accepted**: 16 May 2024

Problem definition

The use of Building Performance Simulation (BPS) to support building design has long been the '*holy grail*' of building science research. BPS can also be used during construction and operation of buildings, for instance supporting rating and certification, optimal control, or fault emulation, but design support is particularly interesting as this is where the foundations for future building performance are laid. The underlying premise is that good predictions of future building performance can inform and improve design decision-making, and thus help to create buildings that are more energy efficient, more comfortable, and overall perform better than buildings that are designed without such predictions. Work on BPS for design support has been carried out since the emergence of building science as a separate area of research in the 1960s (Markus et al. 1972; Clarke 2001; Maver 2002; Augenbroe et al. 2004).

However, the need for better buildings is ever-increasing: beyond the long quest for energy efficiency, thermal comfort and proper lighting, today's built environment also needs to cope with further challenges such as the extreme events caused by climate change, the need to decarbonize in terms of operational as well as embodied energy, remaining healthy in a more polluted world (including fine dust particles, Covid-19 and other sources of concern), while at the same time becoming an active player in terms of energy generation and sharing – see for instance the UN sustainable development goals or various EU initiatives (United Nations 2012; European Commission 2019, 2021). At the same time, the ongoing digitalization and advances in machine learning and artificial intelligence while adding new technologies to the building simulation toolset are potentially changing the role and focus of simulations in building design and project delivery (de Wilde 2023). These new opportunities are fascinating and offer all kinds of novel prospects which combined with high performance, zero-carbon and smart buildings provide a plethora of further possibilities to be explored by the BPS community.

However, the literature on BPS to support design seems to suffer somehow from '*fixation*', particularly in relation to the way it interacts with design practice:

- Too many '*design tools*' presented in the literature are '*solutions in search of a problem*'. Their developers have reduced functionality and focused on what they believe is important to practitioners. But that does not necessarily map to what an actual building designer in practice is looking for (Augenbroe et al. 2004; Bleil de Souza and Tucker 2015).
- Some of the literature presents '*models*' and '*frameworks*' of design that are not operational. They are not grounded on the complexities of design practice which is permeated by liabilities and structured to protect itself from these. Deployable models and frameworks need to provide actionable information such as numbers or workflows in order to be usable, enabling designers to risk assess their actions when deciding to '*jump out of the conventional*' (Bleil de Souza et al. 2023b).
- Some studies also present '*holistic*' solutions to the problem grounded on rarely used procurement processes such as '*Integrated Project Delivery*'; a type of procurement based on deep and continuous interaction between various design professionals, with shared risks and liabilities. Similarly, calls in support of these '*holistic*' solutions fail to provide methods to support their propositions, particularly in relation to information transfer and management, complicating how building performance information and design information are exchanged,

E-mail: pieter.de_wilde@ebd.lth.se

hindering the creation of useful feedback loops between simulation and design (Amorocho 2023; Bleil de Souza et al. 2023b).

- Much of the literature makes rather sweeping and stereotyping statements about various building design professionals such as '*the architect*', '*architectural practitioner*' and '*engineer*' (Attia et al. 2012). They completely dismiss the actual roles these professionals take in practice (senior designer, information manager, project manager, etc.) (RIBA 2020) as well as the level of knowledge they have from experiencing different types of education, careers, and skills beyond basic academic instruction (Alsaadani and Bleil De Souza 2016, 2019).
- Upon close inspection, many papers cite each other on perceived needs and ideas without actually connecting to any hard underlying evidence from the practical world. For instance, there is no consideration for issues related to division of labour and information transfer, or the role of heuristics in decision-making (Bleil de Souza et al. 2023a) in combination with knowledge gained from previous projects (Tucker and Bleil de Souza 2021), all of which contribute to understand how practitioners are likely to interact with BPS. In addition, despite significant efforts dedicated towards creating tools for '*fast feedback*' to designers, improving calculation speed and efficiency of simulation, little attention has been paid to create fit-for-purpose post-processed information for designers to act upon simulation results.
- Much research on using BPS to support design strangely fails to engage in-depth with design research literature, therefore not acknowledging how designers interact with a design problem. They ignore the fact that designers frame the problem by trying to find a solution to it (Cross 2001) and that they undertake specific types of experiments to choose a solution based on what they like better, constantly refining it towards more firm commitments (Schön 1983; Gero 1990) to then present it to the client.
- Theories about building performance are not limited to the traditional domains of building science (building physics) and BPS. There is an emerging body in architectural theory around the topic of '*performativity*' that is worth exploring (Kolarevic and Malkawi 2005; Hensel 2013; Kanaani 2019). Adjacent domains such as construction and facility management also have their own contribution to building performance, for instance in terms of defining the brief for building design and thus setting design requirements and targets for BPS and other types of simulations to be undertaken (de Wilde 2018).

The forementioned points show that the BPS community seems to be missing the realities of what design in practice is about, failing to properly address the use of BPS within this reality, and missing opportunities not only to overcome interesting challenges but also to connect with new opportunities offered by digitalisation and the emerging body of architectural theory in 'performativity' (de Wilde and Bleil de Souza 2019). Time is overdue for the BPS community to properly engage with the reality of design practice in an era of digital transformation, climate emergency and change in values in relation to how buildings should be contributing to neighbourhoods, cities, and citizens.

Design practice '*as-is*'

Some critical notions about what design practice currently is to illustrate the problems highlighted in the section above are presented in Table 1. They are fundamental to understand how BPS can move forward in supporting building design and can be extracted from the grey literature used by practitioners or the literature in design.

Recurrent patterns found in the BPS literature

To prevent new projects repeating earlier efforts, Table 2 summarises previous initiatives to integrate BPS throughout the building design process, so that researchers can assess the novelty of their proposals in relation to them, stating clearly what is novel and where their proposed new efforts deviate from the past research.

Opportunities for the BPS community

Table 1 shows constraints for the BPS community to work within while developing new tools but at the same time, it offers different areas to invest when proposing to assist the design process in practice. If one takes each point highlighted in relation to '*Relevance to BPS-design integration*' the following opportunities appear:

- Can new proposals to integrate BPS throughout the design process factor in interactions between energy, comfort, indoor air quality and CO_2 emissions with other requirements, particularly other measurable requirements, so new multidomain workflows or models can be developed to cater for them? Can proposals considering design theories about requirement independence (Suh 1990) be used to develop new frameworks to account for solution independence?
- New proposals need to collect far more empirical data about the actual interaction between tools in general and design practice to break out of theoretical notions and constructs that lack traction in the real world of design. They need to investigate what exactly happens within each design deliverable stage and list all the activities

Table 1 Design practice, 'as-is' with opportunities and constraints offered to BPS integration

Characteristics of design in practice	Relevance to BPS-design integration
➢ Projects primarily address clients' needs which are transformed into technical requirements and constraints (Bleil de Souza et al. 2023a). However, capturing and managing these requires active work by the design team (Jasuja 2005).	➢ Requirements and constraints need to be elicited in the design brief, and pulled down to the design process (EN ISO 55000 2014; EN ISO 55001 2014; EN ISO 55002 2018). They are augmented with externally imposed requirements, for instance the building regulations. Requirements go beyond energy, comfort, indoor air quality and CO_2 emissions (Bleil de Souza et al. 2023a; de Wilde 2018).
➢ The design process is structured around a clear set of deliverables via procurement routes and contracts subject to approval (RIBA 2020).	➢ Approval from the client, planning authorities and building regulators only enables interactive loops between the design team within project stages (Bleil de Souza et al. 2023a).
➢ Procurement routes, contracts and information delivery plans specify who does what together with the type of information exchanged (Designing Buildings 2024).	➢ There is division of labour in the industry, endorsed through federate building information models, the main digital environment that designers use for their work (EN ISO 19650-1 2018; EN ISO 12006-2 2020).
➢ Every building is unique; a '*prototype*' of one (Bleil de Souza et al. 2023a) responding to site, surroundings, program and client requirements and constraints.	➢ Ultimate design decisions are context dependent and a product of concerted action among the design team and the client, with little room for automation (Hamza and de Wilde 2014; de Wilde 2018).
➢ Within design stages, practitioners '*reflect in action*' by exploring design alternatives, testing the consequences of their actions, or testing hypothesis to act (Schön 1983).	➢ Solutions are chosen based on what the practitioner likes better (Simon 1973; Cross 2001) so digital assistance is welcome for an evidence-based solution to be adopted (Augenbroe 2011).
➢ Design problems are ill-defined (Simon 1973) and characterised by a co-evolution of problem and solution (Cross 2001).	➢ Solutions are constantly reframed towards eventual commitment (Schön 1983; Cross 2001), meaning their assessment needs to cater for uncertainty (Rezaee et al. 2015) while informing future steps.

Table 2 Summary of approaches discussed in earlier works and their appropriateness to design practice

Past initiatives	Appropriateness to design in practice
➢ Use BPS to explore wide design solution spaces or to rank design options.	➢ Design solutions are aimed at convergence, rather than divergence (Jones 1980), a search across multiple options is not common (Schön 1983).
➢ Development of '*simple/simplified design tools*' for architects.	➢ Only valid if these tools are inserted within the microcosmos of '*reflection in action*' (Schön 1983).
➢ Different frameworks to insert cause-and-effect methods to inform design (places for BPS in the process).	➢ Suitable for diagnostics, compliance check, but without post-processing does not contribute to design decision-making (Bleil de Souza and Tucker 2015).
➢ Sensitivity analyses, including parametric design methods.	➢ Appealing to the limited public that tends to use parametric design tools in form finding, not necessarily compatible with BIM and wider design practice.
➢ Use of deterministic choice decision-support systems in BPS to aid design decision-making (multi-criteria evaluation, optimization, etc.).	➢ Mainly applied in detailed phases to select specific design components (Bleil de Souza et al. 2023a).
➢ Interoperability between BIM and BPS tools.	➢ Needs to be further automated, streamlined and potentially post-processed.

designers undertaken in them to realistically propose tools that are fit-for-purpose to also respond to the different levels of resolution design solutions need at every stage.

- It is essential that BPS tools are either inserted or at least have a smooth '*conversation*' with BIM as this is where designers experiment (massing BIM is now being used in the early design stages) with ideas and develop design solutions. BIM ought to provide an excellent platform to integrate with BPS data but the BPS community is far from using it to its potential, missing opportunities to engage with the industry pushing for building Digital Twins.
- New proposals need to acknowledge that ultimate design choices are taken by the client and the top managers of the design team and abandon the idea of promoting '*holistic*' automations for such decisions (either multi-criterion, multi-objective, etc.), but instead to focus on producing useful visualizations to aid them.
- BPS developers also need to understand that digital assistance is primarily welcome when it saves time and provides evidence-base decisions. Time is overdue for modelling to be automated from digital design environments to BPS to speed up the work of consultants and/or enable designers to analyse results while manipulating their digital models, depending on their background knowledge. New opportunities offered by AI and machine learning can be explored, not only to act as simulation surrogates but also to leverage knowledge of practitioners by aiding with interpreting results.

- To be inserted in the microcosmos of practitioner's '*reflections in action*', BPS researchers need to be immersed themselves into this experience to properly experiment with it so that new tools become part of this process rather than a nuisance to it. Experimenting is fundamental to avoid the misconception that '*watchers*' know better than '*doers*'. It prevents stereotyping or simplifying assumptions. The context of 'doing' is starkly different and open opportunities for innovation to emerge.

Note that one needs to be very, very careful about claims regarding the impact of tool development on actual building performance. It is almost impossible to set up a solid scientific experiment that (1) is replicable (2) has one single meaningful intervention whilst keeping all other factors constant and (3) is not open to interpretation bias. It is therefore unlikely that the impact of tools, frameworks, decision-support systems and similar can be validated while used in practice. At best we can ask for a demonstration that shows feasibility in a real design setting.

Properly addressing these challenges will lead to significant innovation and rejuvenation of the BPS-supporting building design research area.

Declaration of competing interest

The authors have no competing interests to declare that are relevant to the content of this article. Pieter de Wilde and Clarice Bleil de Souza are Editorial Board members of *Building Simulation*.

Funding note: Open access funding provided by Lund University.

References

Alsaadani S, Bleil De Souza C (2016). Of collaboration or condemnation? Exploring the promise and pitfalls of architect-consultant collaborations for building performance simulation. *Energy Research and Social Science*, 19: 21–36.

Alsaadani S, Bleil De Souza C (2019). Performer, consumer or expert? A critical review of building performance simulation training paradigms for building design decision-making. *Journal of Building Performance Simulation*, 12: 289–307.

Amorocho J (2023). Decision-making and implementation of renovation solutions in residential buildings. PhD Thesis, TU Berlin, Germany.

Attia S, Hensen JLM, Beltrán L, et al. (2012). Selection criteria for building performance simulation tools: Contrasting architects' and engineers' needs. *Journal of Building Performance Simulation*, 5: 155–169.

Augenbroe G (2011). The role of simulation in performance-based building. In: Hensen J, Lamberts R (eds), Building Performance Simulation for Design and Operation. Abingdon, UK: Spon Press.

Augenbroe G, de Wilde P, Moon HJ, et al. (2004). An interoperability workbench for design analysis integration. *Energy and Buildings*, 36: 737–748.

Bleil de Souza C, Tucker S (2015). Thermal simulation software outputs: a framework to produce meaningful information for design decision-making. *Journal of Building Performance Simulation*, 8: 57–78.

Bleil de Souza C, Tucker S, Deme-Belafi Z, et al. (2023a). Occupants in the building design decision-making process. In: O'Brien W, Tahmasebi F (eds), Occupant-Centric Simulation-Aided Building Design : Theory, Application, and Case Studies. New York: Routlegde.

Bleil de Souza C, Pezzica C, Marchesi M, et al. (2023b). Axiomatic design facilitating integrated building design and operation. In: Proceedings of the 15th International Conference on Axiomatic Design (ICAD 2023).

Clarke J (2001). Energy Simulation in Building Design, 2nd edn. Oxford, UK: Butterworth-Heinemann.

Cross N (2001). Design cognition: Results from protocol and other empirical studies of design activity. In: Eastman CM, McCracken WM, Newstetter WC (eds), Design Knowing and Learning: Cognition in Design Education. New York: Elsevier.

de Wilde P (2018). Building Performance Analysis. Chichester, UK: John Wiley & Sons.

de Wilde P, Bleil de Souza C (2019). Performative design strategies: The synthesis process of a woven complexity. In: Kanaani M (ed), The Routledge Companion to Paradigms of Performativity in Design and Architecture: Using Time to Craft an Enduring, Resilient and Relevant Architecture. New York: Routledge.

de Wilde P (2023). Building performance simulation in the brave new world of artificial intelligence and digital twins: A systematic review. *Energy and Buildings*, 292: 113171.

Designing Buildings (2024). Construction contract webpage. Available at https://www.designingbuildings.co.uk/wiki/Construction_contract. Accessed 11 Mar 2024.

EN ISO 12006-2 (2020). BSI Standards Publication Building construction—Organization of information about construction works Part 2: Framework for classification.

EN ISO 19650 1 (2018). Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)—Information management using building information modelling. Part 1: Concepts and principles.

EN ISO 55000 (2014). BSI Standards Publication Asset management—Overview, principles and terminology.

EN ISO 55001 (2014). BSI Standards Publication Asset management—Management Systems—Requirements.

EN ISO 55002 (2018). BSI Standards Publication Asset management—Management Systems—Guidelines for the application of ISO 55001.

European Commission (2019). Communication: The European Green Deal. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52019DC0640. Accessed 10 Mar 2024.

European Commission (2021). Communication: Directive of the European Parliament and of the Council on the Energy Performance of Buildings (recast). Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0802&qid=1641802763889. Accessed 10 Mar 2024.

Gero JS (1990). Design prototypes: a knowledge representation schema for design. *AI Magazine*, 11: 26–36.

Hamza N, de Wilde P (2014). Building simulation visualization for the boardroom: An exploratory study. *Journal of Building Performance Simulation*, 7: 52–67.

Hensel M (2013). Performance-Oriented Architecture: Rethinking Architectural Design and the Built Environment. Chichester, UK: John Wiley & Sons.

Jasuja M (2005). PeBBU Final Report—Performance based building thematic network 2001–2005. Rotterdam: CIB.

Jones JC (1980). Design Methods: Seeds of Human Futures. New York: John Wiley & Sons.

Kanaani M (2019). The Routledge Companion to Paradigms of Performativity in Design and Architecture: Using Time to Craft an Enduring, Resilient and Relevant Architecture. New York: Routledge.

Kolarevic B, Malkawi A (2005). Performative Architecture: Beyond Instrumentality. New York: Spon Press.

Markus T, Whyman P, Morgan J, et al. (1972). Building Performance. London: Applied Science Publishers.

Maver T (2002). Predicting the past, remembering the future. In: Proceedings of the SIGraDi 2002 Conference, Caracas, Venezuela.

Rezaee R, Brown J, Augenbroe G, et al. (2015). Assessment of uncertainty and confidence in building design exploration. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, 29: 429–441.

RIBA (2020). 'Plan of Work 2020, Overview by Royal Institute of British Architects', Contract Administration. Available at http://www.ribaplanofwork.com. Accessed 12 May 2024.

Schön D (1983). The Reflective Practitioner: How Professionals Think in Action. New York: Basic Books.

Simon HA (1973). The structure of ill structured problems. *Artificial Intelligence*, 4: 181–201.

Suh NP (1990). The Principles of Design. Oxford, UK: Oxford University Press.

Tucker S, Bleil de Souza C (2021). Design patterns for low-carbon buildings: A proposal. In: Littlewood JR, Howlett RJ, Jain LC (eds), Sustainability in Energy and Buildings 2021. Singapore: Springer.

United Nations (2012). United Nations Sustainable Development Goals. Available at https://www.globalgoals.org. Accessed 10 Mar 2024.