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Development and test application of the UrbanSOLve decision-support prototype for early-stage neighborhood design

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ABSTRACT

The need for adequate instruments to support practitioners toward achieving sustainable and energy-efficient architectural and urban design has long been acknowledged. Motivated by identified shortcomings of building performance assessment tools for conceptual neighborhood-scale design, this paper proposes a novel workflow to enable practitioners to efficiently explore a space of design alternatives and compare them in terms of their energy and daylight performance. The workflow includes a multi-criteria optimization algorithm, which is coupled to a performance assessment engine based on predictive mathematical models. To get some insight on the potential added value for design and the usability of this approach in practice, the workflow has been implemented as a plug-in to an existing 3D modeling software and subsequently tested by practitioners during workshops, notably on real projects provided by the participants. Outcomes from the workshops, which include responses from the participants to a pre- and post-test survey, are presented. Results highlight the relevance of the proposed workflow for informing decisions about early-stage building massing on the basis of the considered performance criteria. Improvements envisioned for both the workflow and its implementation are highlighted and discussed.

1. Introduction

The increasing necessity for the building sector to comply with various normative frameworks and performance rating systems has led to the spread of design decision-support (DDS) methods and tools. Ranging from simple rules-of-thumb to advanced computer-based simulation programs, such tools aim at casting light onto the future performance of a project [1,2].

In the domain of building performance simulation (BPS) software, the development has been dominated by workflows supporting the *evaluation* of a detailed building design, whereas less has been done to provide *design* guidance [3,4], particularly of larger scale projects such as that of a neighborhood [5]. Given the rise in urban densification strategies and urban renewal projects [6,7], most developments are located in an existing context and/or hold more than one building. It is thus essential to move from an evaluation over a unique building, considered as isolated, toward an assessment over a larger scale conducted simultaneously on multiple buildings, taking into consideration the impact they have on each other notably in terms of shading [8].

The increased complexity of looking beyond a single building is a strong argument for the need for adequate DDS methods and tools, given that decisions based on intuition or simple guidelines are no longer sufficient [9–12]. This complexity is exacerbated when multiple performance criteria, possibly including conflicting ones, are considered simultaneously. In the design of a neighborhood, anticipating the interactions between new and existing buildings and their impact on each performance criterion, and that, for each of the various designs envisioned, is not a straightforward task to say the least. Yet, such an investigation is essential since early-stage decisions for instance on building massing can lead to significant differences in the performance of a project [13–15].

This paper describes the development, implementation, and test among practitioners of a DDS prototype aiming at providing multi-

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criteria performance-driven guidance during the design of new neighborhoods. We first present in section 2 a review of DDS methods and tools supporting the design process with a focus on BPS at the conceptual design stage. Barriers to the uptake of such tools by designers are highlighted, as well as tool features that could allow bypassing these barriers. In section 3, we describe the proposed workflow that attempts to respond to the identified needs. This workflow forms the basis for the DDS prototype whose development is detailed in section 3.4. The prototype, named UrbanSOLve (Urban SOLar Visual Explorer), is conceived for supporting decision-making over the massing of a neighborhood-scale design in the Swiss context, based on its energy (need and production) and daylight performance. Factors that come into play later on in the design and operation of buildings and that can also alter its performance (e.g., occupant behavior) are beyond the scope of this research. Section 4 describes a test application conducted among professionals to verify the potential of the prototype for fulfilling its purpose in a design process context. Our main findings and conclusions are summarized in sections 5 and 6.

2. State-of-the-Art

2.1. Decision support along the design process

The general domain of DDS methods and tools used along the urban planning, urban design, and architectural design process is practically unbounded and in continuous development. As illustrated in Fig. 1, based on a compilation of information from various sources [16–20], their adoption by practitioners is strongly linked to both the design scale (or spatial resolution, top) and phase in the iterative design process (bottom). The stages depict the evolution from a conceptual (or early) to a more defined (or advanced/detailed) level of the project, a process that occurs whether at the urban planning stage or at the architectural building design phase.

We are here concerned with the moment in the urban design process where there is a transition from 2D to 3D, with building massing, orientation, position and alike being introduced as design parameters [21]. Given the complexities of urban design as mentioned earlier, having recourse to appropriate computer-based software can present numerous benefits, specially building performance simulation (BPS) and visualization types of tools. These have the potential to support the iterative nature of the early design process by facilitating the comparison of different alternatives, in terms of quantitative performance data for multiple criteria, and possibly help designers develop an understanding of the implication of their design choices [3,21]. The latter is crucial, since buildings are typically built to last for a relatively long period (40–50 years [22]), which means that there is a strong lock-in effect in this sector [23]. Locking-in suboptimal design choices, particularly early-stage decisions most of which relate to features that cannot be modified later on (e.g., building shape), would seriously compromise the chance of reaching the increasingly ambitious energy performance targets [23]. Indeed, although not sufficient, strategic decisions regarding conceptual design features are essential for achieving low-energy buildings at a minimal cost. They can decrease the reliance on active (i.e., energy-demanding) systems by lowering heating and cooling loads, while ensuring daylighting [13].

Despite the clear importance of fully exploring passive design strategies from a performance-driven perspective, and the potential for BPS tools to provide a crucial support in this process at the urban design stage, we observe from Fig. 1 that the predominant methods and tools consist of documentation (including standards, guidelines, etc.) and modeling programs (i.e., computer-aided design (CAD) software) to produce drawings. In current practice, the quantitative simulation-based evaluation of a project's energy performance is typically done by an expert only at the more advanced building design stage, often for code-compliance verifications [17,24,25]. Early-design phase actors therefore make decisions with little consideration and/or limited prior knowledge of their impact on energy aspects [13].

2.2. Barriers to the uptake of tools

Limited use of BPS tools in practice has in fact continuously been reported in the literature [17,26]. Surveys conducted among practitioners have shown the main barriers to the uptake of such tools to include (Fig. 2): the complexity of the tools, judged as exceeding the competence domain of the architects, the time requirement, and the lack of integration into computer-aided architectural design (CAAD) software and within the design workflow. These shortcomings can be summarized through the observation that few tools appear to respect and embrace the ill-defined nature of a project in its conceptual stage. In other words, most tools are *evaluation*-oriented rather than *design*-oriented [3,4,27]. They induce a linear generate-and-test process, where form is given priority over performance [28]. Depicted in Fig. 3,

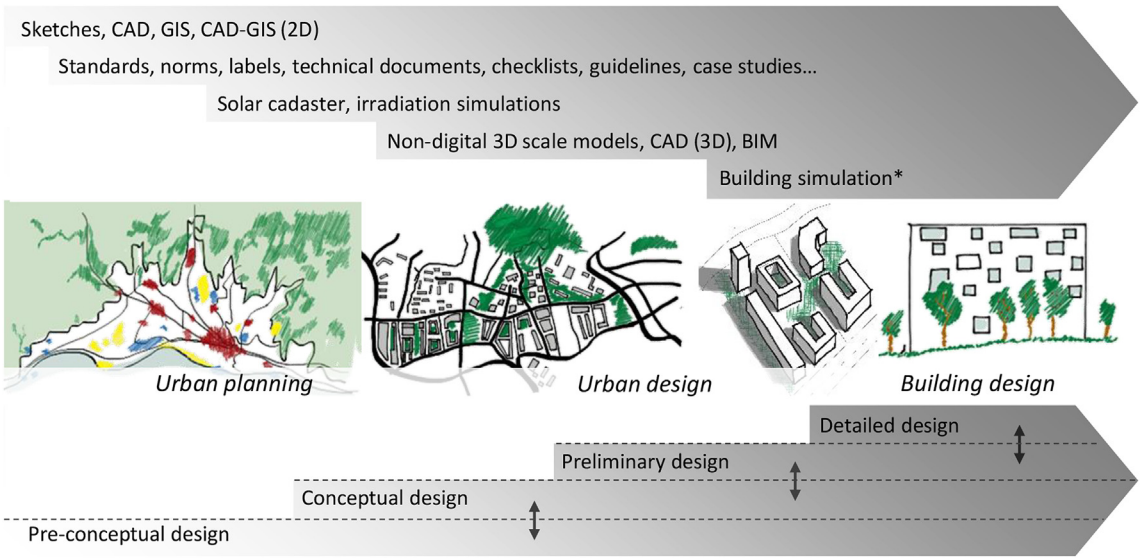

Fig. 1. Main supporting instruments used along the iterative design process, in urban planning, urban design, and architectural building design. *Building performance simulation (BPS) is typically conducted at the advanced building design stage, often by an external consultant or engineer. Schema developed by intersecting and merging elements from various sources [16–20].