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The potential of decision support systems for more sustainable and intelligent constructions: a short overview

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Abstract

Up to now, the performance-based concept has been very rarely extended from engineering phase to other phases within the building process. To achieve more sustainable and more intelligent constructions, the construction industry needs decision support systems that integrate a selection of processes, constraints, time span, and performance criteria that are relevant to all involved stakeholders. This paper intends to demonstrate a design methodology that solves these challenges, and provides several frameworks for decision support systems deemed relevant to the construction industry. Examples of current applications are provided, together with a discussion on future opportunities. The possible synergy with new technologies is emphasized.

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Keywords: performance-based design; construction industry; decision support tool; optimization, sensitivity analysis; design space exploration.

1. Introduction

1.1. Background

Until recently, the so-called prescriptive approach for building processes was in use, mostly for practical reasons: describing acceptable solutions makes the design easy to implement, its verification easy to perform, and regulations easy to enforce. However, Foliente [1] underlined that the prescriptive approach exhibited several serious problems:

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it serves as a barrier to innovation, it makes it very difficult to cost-optimize building construction, and it makes it difficult to compare products from two trading countries that use their own sets of criteria.

A relevant alternative is the performance-based design, which became famously known as "the practice of thinking and working in terms of ends rather than means" [2]. With other words, buildings and building products are thought of what they are required to do, rather than being prescribed how to be constructed. Today, the structural EUROCODES are the most comprehensive example of implementing the performance concept in formal design documents [3].

1.2. State-of-the-art

Spence and Kareem [4] stated that "Performance-based design is fast becoming the benchmark approach for achieving designs that rationally meet society's need for a truly safe built environment". However, appropriate frameworks that allow the principles of performance-based design to be adopted have been mostly restricted to structural engineering of specific types of constructions: e.g. tall buildings [5], to specific construction materials: e.g. concrete [6], or to specific structural requirements: e.g. seismic analyses [7] or wind excitation [8]. Some few studies attempted to combine several engineering disciplines for performance-base design. Among others, Becker [3] considered fire safety, acoustics, moisture safety, indoor air quality and durability in order to formally map the user needs and performance requirements. More recently, Brown and Mueller [9] used simultaneously structural modeling and building energy simulations to generate optimized building shapes.

In general, most multi-disciplinary studies investigated the environmental performance of construction. Caldas and Norford [10] proposed a tool to optimize design solutions in terms of thermal and lighting performance. Later, Ochoa et al. [11] determined the suitability of combined optimization criteria on window sizing procedures for low energy consumption and high visual comfort. Wang et al.[12] presented a methodology to optimize building shapes in plan by considering both life-cycle cost and life-cycle environmental impact. Fabrizio et al. [13] customized their modelling approach to integrate different energy sources in order to cover the thermal and electrical loads of a building. Nguyen et al. [14] gave a complete review on "building design optimization", although the scope of their work was limited to the design of "greener" buildings, without taking into account other types of requirements. At the same time, there is a recognized lack of suitable tools for early design of for example environmental objectives [15, 16].

Up to now, the performance-based concept has been very rarely extended from engineering phase to other phases within the building process, particularly those occurring after the construction, although they may have a substantial effect on the required level of investment. The whole building process is still following a very linear workflow despite studies that suggest to enhance interdisciplinary in order to reduce the investment in poor performing solutions [17].

Despite the strong need for highly efficient structures motivated by rapidly decreasing resources and high construction costs, structural optimization methods that prioritize efficiency have not taken hold in practice [18]. Bakens, Foliente and Jasuja [19] insisted on the fact that to engage stakeholders effectively, the performance approach should be presented as a business issue rather than primarily as a technical issue. Cost is maybe the most crucial business issue: e.g. Marks [20] determined the optimal dimensions of a building by minimizing the building and heating costs. However, environmental issues are increasingly studied at the design phase: e.g. Fesanghary et al. [21] attempted to satisfy the multiple objectives of energy consumption optimization, financial costs reduction and decrease of environmental impacts. Other important business issues, e.g. construction time, health and safety, and societal cost, have been very seldom investigated within such frameworks. In general, eliciting the needs and requirements of all stakeholders is necessary, as these may not be aligned [22].

1.3. Main motivation and objectives

Decision support systems should intend to integrate a selection of processes, constraints, time span, and performance criteria that are relevant to all involved stakeholders. The "design team", which is usually limited to architects and engineers, should instead encompass also manufacturers, entrepreneurs, future owners, users, etc and should make use of the "performance-based design" concept in a very broad sense.