An integrated ontology-based approach for optimizing structural design at early stage with consideration of environmental impact and cost

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Abstract. Early stage decision-making for structural design critically influences the overall cost and environmental performance of buildings and infrastructure. However, the current approach often fails to consider the multi-perspectives of structural design, such as safety, environmental issues and cost in a comprehensive way. This paper presents a holistic approach based on knowledge processing (ontology) to facilitate a smarter decision-making process for early design stage by informing designers of the environmental impact and cost along with safety considerations. The approach can give a reasoning based quantitative understanding of how the design alternatives using different concrete materials can affect the ultimate overall performance. Embodied CO_2 and cost are both considered along with safety criteria as indicative multi-perspectives to demonstrate the novelty of the approach. A case study of a concrete structural frame is used to explain how the proposed method can be used by structural designers when taking multi performance criteria into account.

Keyword: Holistic Structural Design, Ontology, Environmental Impact, Lifecycle Cost, Multi-Criteria Decision Support

1. Introduction

A building project is chronologically composed of three main stages, namely the design, construction, and use phases. The potential for influencing environmental impact and cost performance is very high in the design stage, and decreases dramatically with the progression of time (Kohler & Moffatt, 2003). This means that a large number of building decisions are made by designers in the early phase, and this critically determines a building's ultimate performance. Structural engineers, as a key part of the design team, work alongside architects and MEP (mechanical, electrical, plumbing) engineers to ensure that buildings are strong enough to withstand all kinds of loads and actions. During the building design process, structural engineers normally pay more attention to safety and technical issues than environmental impact and cost concerns; this is because decisions related to this aspect largely hinge on the architect and client, which means that their contribution to the environmental performance is negligible (Miller & Doh, 2015). Recent years have witnessed an increased awareness of the fact that structural engineers can make significant contributions to the reduction of environmental impact and cost. However, this is only possible if they pay a great deal of attention to the sustainability and cost, because a large amount of structural material is used in structures (Wolf, et al., 2017). Additionally, attention must be paid to the various indirect benefits of structural design, such as increasing the overall net area and net height, improving lifespan, shortening the construction schedule, and reducing labor and equipment. All of these factors influence overall performance with regard to environmental impact and cost.

However, despite this growing awareness, structural engineers commonly fail to combine environmental issues and cost into a holistic structural design. This is due to the fact that, in