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Title: Guiding building professionals in selecting additive manufacturing technologies to produce building components

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Abstract

Buildings made of additively manufactured (AM) components are likely to have higher energy efficiency and environmental sustainability than conventionally manufactured (CM) buildings. AM building components can be highly customizable, produced with less material, and installed rapidly due to simplified or eliminated connections. Given the continued development of AM and CM technologies and the many market and use scenarios of buildings that prioritize different performance criteria, building components will likely be produced with a mix of AM and CM technologies for the foreseeable future. However, since building professionals are not informed about the value of AM through transparent metrics like cost and environmental impacts they are unable to make well-informed decisions about the application of AM in the building sector.

Case studies of two AM metallic building components, a large window frame and a bracket, carried out by the authors in collaboration with a global building façade contractor demonstrated that AM for building components is technologically feasible and can lower environmental impacts by up to 87%, but is cost-prohibitive given the number of components in a building and the time available to fabricate and install them (in some cases, the manufacturing cost and schedule were about 90% higher and 91% longer respectively).

Based on the case studies, a 19-step assessment method was developed with the aim to allow building professionals to rapidly and consistently assess the applicability (A), schedule (S), environmental impacts (E), and cost (C) of producing building components with AM vs. CM. The formal, partially automated application of the method showed that it reduces the effort required for the ASEC analyses by 97% and improves the consistency of the A, S, and C analyses. However, the inconsistencies of the environmental impacts (E) analysis remained due to the inherent flexibility of the life cycle assessment (LCA) method standardized by ISO14040. Future work includes fuller automation of the method, generality tests and extension of this approach to other industry sectors.

Keywords: additive manufacturing; conventional manufacturing; assessment method; applicability; schedule; manufacturing cost; environmental impacts.

1. Observed problem

Today's practices of manufacturing building components are not environmentally sustainable [1][2]. Conventional manufacturing (CM) in the building sector is responsible for high-energy consumption, solid waste generation, global greenhouse gas emissions, environmental damage, and resource depletion. New manufacturing approaches are required to reduce these environmental impacts across all areas of building component production while enabling sustainable growth. Additive Manufacturing (AM), popularly known as 3D Printing, represents such a breakthrough technology [3][4][5][6][7].

Building professionals are starting to understand the benefits of AM technologies [1][2][3]. AM components could be highly customizable, produced with less material, and installed rapidly due to simplified or eliminated connections in comparison to CM components. Given the continued development of AM and CM technologies [4][5][6] and the many market and use scenarios of buildings that prioritize different performance criteria, building components will likely be produced with a combination of AM and CM technologies for the foreseeable future. Nonetheless, interviewed building professionals showed lack of knowledge about the value of AM in the building industry, specifically about crucial metrics like cost and environmental impacts. "What are the specific 3D printing technologies that we can use to manufacture a specific building component? How much would it cost and how long would it take to use these technologies? What are the environmental impacts of such technologies in comparison with the traditional manufacturing methods we use now?" If building professionals were informed about the value of AM through transparent metrics in a systematic and timely manner, they could make well-informed decisions about the application of AM [8]. Such metrics could be included in (design) software packages used in the building industry.

Motivated by the observed problems, the authors conducted detailed case studies on building components to assess the value of AM. Based on the studies, an assessment method was formalized with the goal to rapidly and consistently inform building professionals about the multi-criteria comparative rationale of AM and CM for producing specific building components. Finally, the authors applied the method