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How circular economy and digital technologies can support the building sector to cope with its worldwide environmental challenge?

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The building sector can address pressing environmental problems by leveraging two major trends: circular economy and digital technologies. Circular building practices emphasize restorative design principles, which can significantly reduce the amount of virgin material used and the environmental footprint of buildings. When combined with digital technologies, circular practices can achieve even higher environmental benefits. Such technologies enable visualization of the environmental impact along the entire value chain, facilitating smart design, production, and use to increase material- and eco-efficiency. However, realizing the full potential of these trends requires more than just technological advancements. Institutional, behavioral, and socio-economic system changes are essential to effect a transition towards a circular and digital economy. To facilitate such a transition, a new form of governance is needed, in which network governance complements conventional public governance. Network governance fosters the formation of coalitions of willing partners that jointly strive towards the goal of system change, creating a fertile ground for a new economic paradigm, behavioral change, government regulation and innovation. The effectiveness of network governance in supporting public governance depends on the specific socio-cultural and political context of a country. However, a thoughtful application of this governance model can facilitate the building sector's journey towards greater material- and environmental efficiency.

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INTRODUCTION

The building sector is confronted with the imperative of accelerating its environmental performance. Currently, building and construction generate 36 percent of global energy consumption, produce 40 percent of waste and account for roughly 40 percent of carbon dioxide emissions worldwide[1]. To tackle these environmental challenges, the building sector must capture the opportunity that two major trends provide: digital technologies and the circular economy. This article explains why these trends can be critical for mitigating the environmental impact of the building sector and outlines strategies for how their implementation can be achieved and accelerated.

DIGITAL TECHNOLOGIES

The application of digital technologies can benefit the building sector by making the building process more material- and eco-efficient[2]. A broad field of digital technologies are available and continuously scaling, including artificial intelligence, big data, cloud computing, cyber physical systems, blockchain and virtual and augmented reality[3]. However, the building sector has just begun to adopt these emerging technologies. Integrating these technologies into daily work processes would significantly add value to the sector[4]. For instance, data management tools—such as Building Information Modeling (BIM), material passports, lifecycle analysis and material flow analysis—can enhance transparency about the environmental performance of the entire building chain and provide insight into how the chain can become more eco-efficient[5].

The broad field of virtual and augmented reality can provide a 3D understanding of how a building is constructed, with what materials, and how this can be attuned to the needs of the customer. In addition, it can optimize resource use during the construction, maintenance, and end-of-life phases. An example is the use of digital twins[6]. This is a virtual representation of an object or system that spans its lifecycle, is updated from real-time data, and uses simulation, machine learning and attendant reasoning to help decision-making, also about material-efficiency[7]. In addition, 3D printing offers a greener building technique that eliminates a great amount of CO_2 emitting and energy-consuming processes compared to conventional building techniques[8]. Thus, digital technologies can help improve the environmental performance of buildings, particularly when combined with the circular economy.

CIRCULAR ECONOMY

The concept of the circular economy is simple yet urgent. It highlights the fact that we are overconsuming natural resources, some of which are scarce, on a global scale. In 1970, we only needed one earth to provide mankind with the necessary resources; nowadays we need 1.75 earths. If we continue on our current path, we will require 3 earths by 2050[9]. The Circular Gap Report has revealed that our world is still largely linear[10], as we only bring 8.6% of what we use back into the cycle, resulting in a Circularity Gap of over 90%. To address this issue and become more prudent with raw materials, energy, and water, pleas are made to move to a circular economy[11]. There have been various definitions for the term 'circular economy'[12]. However, the common denominator is that it is restorative by design and aims to keep products, components, and

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materials at their highest utility and value, distinguishing between technical and biological cycles[13]. This notion is particularly significant important for the building sector because of the high percentage of waste produced. However, this sector is characterized by strong project-based institutionalized practices and market mechanisms, which in many aspects do not facilitate the inclusion of circular economy principles[14].

Technically, it is possible to consume far fewer raw materials in the building sector and drastically reduce CO_2 emissions. We can extend the lifespan of buildings, redesign them with circularity in mind, reuse parts of them and recycle their materials[15]. Three Dutch examples serve to illustrate the benefits of building with circular economy principles. For instance, the distribution system operator Alliander—an entity responsible for distributing and managing energy to final consumers—opened its new office in 2015 in Duiven. Although everything about the building exudes style and newness, almost nothing in it is actually new. In fact, 83% of the materials used in the building are recycled. Similarly, in the new Venlo town hall (established in 2016 in the Netherlands) all the raw materials used in the construction can be fully reused with no loss of value. Moreover, the town hall building is entirely energy neutral, thanks to features such as solar panels, thermal energy storage, and solar boilers. The Green House pavilion is the final example, designed to be temporary, as the municipality of Utrecht has plans to redevelop the area in 15 years. The construction used as many recycled materials as possible, which will also be reused when the building is removed. And ultimately, when that happens, there will be no trace left of The Green House in or on the land. The building's construction is designed to ensure that no pipes, cables, or sewage will remain in the soil under the pavilion, thus minimizing its impact. However, scaling up such iconic projects and making circular building mainstream remains a significant challenge. It requires system innovation, in which technological change goes hand in hand with a socio-economic and behavioral change. The main obstacles to realizing this system change include a focus on short-term goals, complex supply chains, a lack of collaboration between stakeholders, and the absence of a commonly agreed definition of the circular economy within the industry[16].

GOVERNANCE

Experiences in circular economy have demonstrated that the aforementioned obstacles can be overcome with effective governance during the transition to a circular system[17]. This shift requires a fundamental departure from the current linear system in which products are carelessly discarded after use. No single entity, whether it be a company, local government, or NGO, can undertake such a comprehensive system change on their own. Collaboration among partners who are committed to contributing to the change is necessary to establish a robust network. To ensure its efficacy, this network should be orchestrated through a concept known as 'network governance'. Network governance is not meant to replace conventional public governance, but rather to complement it. It facilitates the attainment of circular objectives and strengthens societal support for more stringent government measures.

A comparative study encompassing 16 countries has illustrated that network governance can offer substantial added value[18]. However, the extent to which network governance can support public governance is contingent upon specific socio-cultural and political contexts[19]. For instance, in countries where the government takes a strong leadership role in circular economy and receptivity towards network governance is high, the conditions for initiating and accelerating circular economy are propitious. The Dutch circular building examples mentioned above serve as a case in point. In contrast, where both forms of governance are weak, it is more arduous to launch circular initiatives. Nevertheless, opportunities for developing circular economy can be identified in all 16 countries studied. In Australia, for instance, industry, government, and NGOs exhibit a rather antagonistic attitude towards one another. However, this does not preclude cooperation among these actors in sectors such as building; it simply necessitates additional incentives. For example, when commissioning parties cooperate in restructuring an urban area and implementing circular strategies, they can urge the network of contractors to exchange data and adopt an integrated circular approach. Digital technologies can reinforce such cooperation.

Hence, the building sector worldwide can make substantial strides on the path to circular economy when new forms of network cooperation among pertinent actors are implemented in conjunction with government leadership. Individual actors frequently hesitate to assume leadership roles in system change, as they do not perceive it to be their core business and await others to step forward. To resolve this predicament, independent intermediaries, known as transition brokers, can play a pivotal role in orchestrating the change process. They can align actors with divergent interests around a shared vision and resolve impasses. To be effective, transition brokers must possess a specific set of competencies and acquire the mandate to function as intermediaries. Once accepted, transition brokers can accelerate the process significantly.

Researchers can also contribute to the transition towards a circular building sector. However, to render their research socially relevant, individual projects should be clustered around themes that collectively portray the broader picture of transitioning to a circular economy. In this way, research can be mobilized that centers on fundamental solutions confronting society today. Generalists with sufficient knowledge about the variety of innovations and the specifics of the building sector are certainly equipped to bundle research and highlight the most promising innovations. These knowledge brokers can facilitate the utilization of research in practical applications in the building sector, in the short or long term[20]. This would enhance the value of the arduous work undertaken by numerous researchers in the field of the built environment.

DISCUSSION

The building sector can address pressing environmental problems by leveraging two major trends: circular economy and digital technologies. Examples have been provided to illustrate this observation. However, realizing the full potential of these trends requires more than just technological advancements. Institutional, behavioral, and socio-economic system changes are essential to effect a transition towards a circular and digital economy. To facilitate such a transition, a new form of governance is needed, in which network governance complements conventional public governance. A thoughtful application of this governance model can facilitate the building sector's journey towards greater material- and environmental efficiency.

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