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Abstract. Regenerative approaches have gained attention in the built environment, but remain highly conceptual. This position paper argues for new regenerative governance structures that consider data governance, reassess complex stakeholder interactions, and ensure the inclusivity of diverse values and ownership. It then presents early ideas on how blockchain technology could facilitate scalable socio-economic-ecologic interactions along three inquiries, giving practical examples. Overall, the paper aims to inspire and guide further research into the development of modern digital governance tools fostering a regenerative built environment.

1. Introduction

The concept of regenerative design and development is increasingly discussed in the context of the built environment [1]. A regenerative worldview requires a radical shift in mindset, wherein humans are considered co-creators and contributors to the Earth system as a whole, instead of treating natural resources as solely existing to serve human purposes [2–4]. This is in contrast to other paradigms for sustainability where the discourse focuses on improving the current status quo [3].

However, the current scholarship on the regenerative built environment remains highly conceptual. Scholars often suggest helpful frameworks or standards for regeneration, but rarely provide specific approaches or technological possibilities for implementation [1,5].There are some examples emerging in practice (e.g., the Living Building Challenge [6]), but the complexity and scale of urban environments, along with issues of economics, incentives and coordination, have hindered the widespread adoption of regenerative principles in the built environment [2,7]. Several studies suggest that implementing a governance system for regeneration (i.e., the process and structure for making and enforcing regenerative decisions across scale and sectors) remains a major unsolved challenge [8–10].

In this position paper, we suggest that a regenerative built environment requires the development of a new governance approach along three lines of inquiry. First, there is a need to rethink data governance in alignment with the regenerative principles found in the fast-changing technological landscape of the 21st century, especially in regard to data collection, distribution, maintenance, and evaluation. Second, there is a need to reassess stakeholder roles, responsibilities, and ramifications for governance relations in complex regenerative systems [4]. Third, there is a need to develop a new approach to the governance of value and ownership of non-human entities, including both buildings and nature, to enable a harmonious coexistence in the built environment [1,9,11].

From this departure, we next argue that the characteristics of blockchain technologies could play an important role in addressing these needs. Blockchain technology(BT) offers potential solutions by enabling new forms of economic coordination without intermediaries and encoding interaction rules directly between agents [12–14]. Further, it has the potential to encode scalable socio-economic interactions [15] to better enable governance of information, governance of procedures, and governance of ownership and values. This paper provides a starting point for further research into a possible blockchain-based approach of governance structures of the regenerative built environment.

2. Concept to Practice: Governance Challenges for Regenerative Built Environment

In recent years, many approaches within the built environment have emerged to reduce and eliminate negative environmental impact caused by human activity, such as ecological design [16–19], sustainability [20–22], green buildings [23,24], and circularity [25,26]. There exists several discourses on the conceptual overlap and distinctions between regenerative and other sustainable strategies [22,24], the main difference lies in the paradigm shift that regenerative built environment calls for, where humans, buildings, and nature are viewed as equal participants. The realization of paradigm shifts often requires the implementation of a new governance system, encompassing organizational control, operation, and the accountability mechanisms. By contrast, most other sustainability strategies are often viewed as an improved condition or standard for traditional buildings and can operate within existing paradigms and governance systems. Through a review of regenerative built environment literature, we identify three governance challenges: data and information across disciplines, the relationship between cause and effect, and the ownership and value of actors and entities.

2.1. Information-integrated tooling

The inherent breadth and complexity of regenerative frameworks pose significant challenges to their practical applications and evaluations of their efficacy [1]. Orova and Reith addressed the importance of key performance indicators for digital processes and the need to investigate the quantification of "soft" qualities such as social equity in regenerative design [11]. Yet, there is a lack of discussion on the practical incorporation of regenerative design into existing digital processes [1]. One such effort is the REGEN framework, a regenerative benchmark and standard that derived from existing sustainable frameworks [27]. This framework encompasses the well-being of the natural system, the performance of the construction system, the prosperity of the economic system, and the equity of the social system.

While incorporating economic and social dimensions with sustainable building metrics is a good starting point, it falls short in representing regenerative ideas by the strict isolation of different objectives. There are inherent social implications and economic values embedded in building information, and these factors cannot be addressed separately. For example, collecting data to optimize building performance is not just a technical process; it has social and economic implications. The way data is collected has implications for user privacy and security, while the purpose and accessibility of the data determine its economic value and its beneficiary. These regenerative design aspects should not be treated as add-ons but should be integrated into the information technology architecture and processes themselves. The governance of information, including the underlying technology stack, should embed regenerative principles by design, with system transparency, trusted system logic, and equitable information access.

2.2. Complex and co-evolving living system

The concept of the living system was introduced by Larrick in 1997, as a complex system approach to managing human development, community thriving and long-term sustainability [28]. The living system perspective is widely accepted and incorporated in some of the most prominent emerging frameworks for regenerative paradigms and frameworks, such as LENSES [29], Living Building Challenge [6] and REGEN [27]. The coordination of the complex living system requires 1) a fundamental understanding of the system boundary, 2) the identification of changing patterns in the system across scales, 3) an understanding of this change over time [30], and 4) the consideration of inputs, outputs, behaviours and incentives in a complex manner [31].

In other words, a regenerative framework requires an economic model beyond the conventional cost-and-return approach to reinforce structural inequalities and disregard sustainability concerns [7]. For example, Axinte et al. has established a regenerative city-region framework that leverages economic rationales with regenerative aspirations [2]. A new field of research called regenerative economics has emerged to address the importance of considering economic incentives for a regenerative future [11], which can be adapted for the regenerative built environment.

The adoption of a regenerative strategy also requires the engagement and cooperation of all stakeholders in order to achieve long-lasting sustainability [28,29]. Social equity, collective governance, and human well-being play an important role in regenerative frameworks [1,3]. Craft et al. developed a conceptual decision-making framework to facilitate the collaborative governance of regenerative communities [8]. Mang and Reed further identified the challenge of fragmented institutions, policies and governance in the built environment [4]. Overall, the primary challenge in advancing regenerative practices lies in establishing a new social-economic-technological coordination that is inclusive, scalable, reliable and adaptable for collective governance of the local communities.

2.3. Inclusive ownership and values

The regenerative built environment requires a nature-centric value system for a harmonious relationship among humans, nature and the building. Conventional approaches in the built environment often treat nature as an embellishment of the city, isolating human creation from natural creation. Two most significant approaches, biomimicry and biophilic urbanism, aim to integrate nature into the built environment. While the former aims at the strategic emulation of natural engineering; the latter focuses on the connection between human and nature [32,33]. One of the most notable city-level biophilic urbanism cases is the “Garden City" vision of Singapore. By prioritizing environmental factors such as biodiversity, and air and water quality, Singapore increased its vegetation coverage while mitigating the effects of intensified population density [34,35]. Beyond biomimicry and biophilic methods, the regenerative design seeks to restore, tend, and – as its highest goal – even “be nature” [36]. To achieve this, it is necessary to include values beyond mere efficiency and profitability and shift away from a paradigm where humans are the sole owner of everything on earth.

“Soft” values are at the core of regenerative design, such as the culture of local communities [37]. The regenerative place-based approach of the “Design from Places” framework [4] involves the consideration of the environmental and social contexts of the site, including the history and cultural significance of the area, termed “the story of place” [34]. Understanding the places’ and the human role within is the basis for establishing a complex, adaptive and holistic living system [4,37]. In addition to non-monetary human values, the value of nature should also be reflected and manifested in the regenerative system. The Rights of Nature is a legal movement that advocates for the inherent rights of nature [38], and a recent victory is the Whanganui River Agreement, in which a river in New Zealand is legally recognized as a living entity with rights of its own equivalent to human rights [39]. A true regenerative system demands a radical transition of ownership and values, calling for broader inclusivity of it beyond the human-centric view. However, while the conceptual goals are clear, there remains a lack of technical solutions to achieve this.

3. Blockchain for Regenerative Governance

Achieving regenerative development requires addressing significant challenges in managing complex systems and understanding the intricate and sophisticated relationships between data, information, incentives, actions, stakeholders, value, and ownership. The centralized value system inherent in traditional non-technical governance approaches can undermine the inclusion of diverse perspectives, hinder the realization of equitable outcomes across nation boarder and subpar the efficiency in managing complex systems [40]. Conversely, local community oriented governance, while beneficial for value inclusivity, suffers from the tragedy of the commons [41] and difficulties in scaling [42]. Therefore, a transformative governance tooling that tightly unites social, economic, and technological aspects is pivotal in advancing regenerative development to a higher level of effectiveness. Visionary researchers explored BT’s potential in establishing new economic coordination [43], value-sensitive complex system design [44] and to form new transparent, code-based legal institutions [45]. This chapter illustrates in detail the potential of BT to achieve 1) governance of information, 2) governance of procedures, and 3) governance of ownership and values.

3.1. Governance of information

BT enables peer-to-peer transactions between agents solely identified by their blockchain address, eliminating the need for intermediates [46,47]. As one of the system properties, data is stored immutable and transparent in its distributed ledger. This enables monitoring of events to facilitate trust and accountability within a regenerative system, forming the basis for trusted data management. For example, to identify and learn from patterns of behavior for better adaptation, or to certify and approve actions in line with regenerative principles. Recent examples from supply chain management, such as WWF's tuna tracking [48], show how increased data transparency can drive more responsible resource sourcing. In addition, trusted system logic is enabled by Smart Contracts, which can ensure the trustworthy execution of workflows in regenerative systems. By decentralizing system logic, they enable more efficient coordination of complex interactions among humans, machines, and nature. For example, smart contracts can encode the rules for the creation and distribution of local and decentralized renewable energy networks [49,50], as piloted in Brooklyn microgrid project [51]

Blockchain also ensures equitable information access. Address-based identity and unrestricted network access allow for equal opportunity for all agents to participate in the system and access information related to the system's history, current events, and the system logic for future coordination. This inclusivity enables participation regardless of whether the agent is human, machine, or natural. For example, terra0 [52] and Sovereign Nature Initiative [53] aims to create a technologically-augmented ecosystem around a forest within a predetermined set of economic rules, treating the forest as an agent in its own right.

3.2. Governance of procedures

The emerging concept of Decentralized Autonomous Organizations (DAOs) provides a community-based and logic-centred structure for economic coordination [54,55]. DAOs could use smart contracts to facilitate consensus processes and promote the development of radical economic models for the governance of regenerative procedures. This can occur through decentralized economic production. Decentralized markets and investment mechanisms can integrate and harmonize coordination of economic activities among all agents, in accordance with regenerative principles and resource constraints. An exemplary decentralized mechanism to incentivize investments in public goods is the augmented bonding curve developed for the Commons Stack [56]. Blockchain-based decision-making and voting tools also allow for collective governance, through transparent and collective creation of governance processes. This ensures the alignment of the community with procedures intended to foster collaboration and compliance. The use of decentralized conflict resolution could resolve disagreements between agents, be it humans, machines, or nature. Early frameworks like Kolektivo [57] intend to provide algorithmic DAO tooling for community governance of regenerative economies.

3.3. Governance of ownership and values

Smart contracts can encode transferable containers of value as tokens [15]. This allows for bottom-up value creation and transfer in regenerative systems. Furthermore, blockchain can engineer ownership for human and machine agents [58], encoding rights, incentives, and boundaries to non-human entities. The concept of inclusive ownership means that people, buildings, and nature can participate equally in the natural cycles and processes of the ecological system [36,59]. Theories such as Nature2.0 [60] imagine self-sustaining infrastructure ecosystems, prototyped in the no1s1 project with a self-owning house [61]. In all, BT facilitate the transcend of existing anthropocentric ownership structures, laying the groundwork for a more inclusive and equitable system.

Tokenization also allows for the representation and encoding of inclusive values, potentially enabling a shift in economic models towards net-positive regenerative outcomes. Current financial systems are limited in their ability to represent values beyond monetary ones. Token-represented value in DAOs can enable the representation of values of both humans, the built environment, and nature, and provide incentives for the adoption of regenerative practices. Examples of tokenization could include carbon credits [62] and the issuance of new currencies representing community-defined values, as explored by the Finance4.0 project for sustainability [44].

4. Conclusion and Future Research

This position paper describes how the lack of governance systems is one of the key challenges facing the wider implementation of the regenerative built environment. Without addressing the governance of information-integrated tooling, complex and co-evolving living systems, and inclusive ownership and values, it will be difficult to move research on the regenerative built environment beyond conceptual frameworks. This paper suggests that BT could be an effective governance tool to help overcome these challenges by creating socio-economic-ecologic governance structures for information, processes of complex systems, and inclusivity of ownership and value. For each category, the paper provides a summary of the technical capabilities and their potential application, along with an example from applied research or practice. Based on the early thinking in this paper, the following research directions can be explored as next steps: value-sensitive data collection in smart infrastructure, data management for regenerative built environment, and adaptive regenerative governance mechanisms.

While BT has been proposed as a solution for regenerative built environment governance, it is important to critically assess the advantages and limitations of such an entirely new system compared to existing approaches. The decentralized nature of BT poses challenges in terms of flexibility and scalability, as it relies on a distributed network for data storage and processing. Additionally, the immutability characteristic of blockchain, which ensures data integrity, can hinder adaptability as modifications or updates to information recorded on the blockchain become difficult. Moreover, its transparency, promoting openness and auditability, can present challenges to privacy of data, potentially compromising sensitive information. These limitations should be carefully considered in the future researches evaluating BT for regenerative applications.

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