COULD GREEN BUILDING CERTIFICATION SYSTEMS BENEFIT FROM THE INTRODUCTION OF BLOCKCHAIN? A SYSTEMATIC REVIEW

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Abstract

We investigate the Green Building Incentive mechanisms to overcome identified barriers in adoption. With the aim of increasing the overall efficiency of the certification system, integration with the blockchain is proposed. Further, the blockchain concept and its applications are introduced. Blockchain-related incentive mechanisms and their intricate relationship with design and governance are also highlighted, through a systematic review. We conclude with the need for a stakeholder survey for the most suitable blockchain design and governance.

Introduction

The construction industry's impact on sustainability highlights the need for green buildings Jayakody and Vaz (2023). Measuring a building's sustainability performance becomes crucial as we strive to mitigate negative consequences. In response, several versions of the Green Building Certification System (GBCS) have evolved to measure a building's sustainability performance Braulio-Gonzalo et al. (2022). Despite its importance, barriers hinder the widespread adoption of green building certification Agyekum et al. (2019). In response, incentive mechanisms have been introduced, but their effectiveness still needs to be improved Olubunmi et al. (2016). Lack of sufficient motivation for green building certification drives exploration into innovative solutions, with blockchain emerging as a promising option.

Blockchain technology introduces a decentralized and secure way to manage records Turk and Klinc (2017). With their ability to represent various incentives, blockchain applications expand to the construction industry, offering viable solutions to the barriers encountered by GBCS . However, an effective application for GBCS requires careful consideration of BC design and governance Fan and Wu (2020).

This article explores the relationship between blockchain, governance, and incentives, examining their roles in potentially improving green building certification adoption. Investigating stakeholder perspectives becomes decisive because their preferences are the main driver for a tailored blockchain design in the green building certification area. This study reveals blockchain's potential to advance GBCS by promoting sustainability through efficient governance and alternative incentive mechanisms.

The article's structure is as follows: in the first section, we delve into green building certification and examine barriers to its adoption. Moving to the second section, we introduce blockchain technology and its application requirements. In the third section, we investigate the capabilities of blockchain in GBCS. Finally, we conclude by harmonizing key insights and proposing future research.

Methodology

To conduct a literature review and define the knowledge gap, we researched relevant articles in Google Scholar. We utilized Boolean operations to filter our search with the following keywords: "blockchain AND green building certification AND incentive mechanisms", "blockchain AND sustainable building AND financial incentives OR non-financial incentives", and "blockchain AND green building certification AND financial incentives OR non-financial incentives". These keywords were determined based on their relevance and incorporation with the key topics of research; blockchain, green building certification, and incentive mechanisms. We also applied the snowballing technique to improve the literature review's comprehensiveness. During the primary research, we identified two key articles and then extended the literature pool by systematically examining the references cited in these articles. This iterative process helped to collect broader relevant literature. Eventually, in our literature review process, we identified 82 relevant papers. These papers are examined to identify their alignment with the research objectives and key topics. Only articles published in English are taken into account. Articles published before 2000 are excluded from this study to provide a contemporary and relevant analysis. Relevant doctorate and masters' theses are also not included in the scope to focus and prioritize peer-reviewed research publications. For purposes of this research, we selected to present papers discussing the intersection of blockchain and green building certification systems, primarily focusing on the incentive mechanisms and their impact on sustainability and innovation in construction.

Why Green Buildings are Important?

The building sector is criticized due to its high energy and resource consumption. A recent study by Jayakody and Vaz (2023) stated that buildings constitute nearly 70% of the total energy consumption in the United States and around 35% globally. In addition to energy usage, buildings have a significant impact on other natural resources, contributing to 35% of greenhouse gas emissions, 50% of extracted materials, and approximately one-third of both water consumption and waste worldwide, as highlighted in another recent study by Braulio-Gonzalo et al. (2022).

The concept of green building has emerged as a response to the adverse impacts of construction on the three pillars of sustainability: environmental, social, and economic. It is a primary tool for advancing sustainability objectives within the construction industry as stated by Karji et al. (2021). Green buildings, alternatively called eco-friendly or low-energy buildings, are intentionally designed to alleviate stress on resources by limiting negative impacts on human health and addressing challenges like resource scarcity.

Green building contribution extends beyond environmental considerations; it is inherently connected to social sustainability. Green buildings support creating a healthy environment, fostering community, and boosting human productivity. As stated in Goh et al. (2020), they "complement their environmental impact, creating sustainable and livable spaces that promote a higher quality of life for individuals and communities."

Embracing green building practices has a substantial impact on all three sustainability pillars. Beyond the environmental and social perspectives, green buildings present economic advantages. Effective implementations result in cost savings throughout their lifespan and offer stakeholders the chance for increased profits. In essence, green building practices provide noticeable benefits both environmentally, socially and economically Olubunmi et al. (2016).

What is the GBCS?

Measuring the performance of development is fundamental for ensuring its contribution by establishing standards, aligning goals, and identifying successes and challenges. Braulio-Gonzalo et al. (2022) details that performance measurement optimizes resource allocation, supports the decision-making process, and exhibits the tangible impact of development initiatives.

Standards and frameworks used in the sustainability assessment are typically established by internationally recognized organizations such as ISO, GRI, etc. These institutions develop and define global standards that become laws or serve as the foundation for industry. Standards specify requirements in two ways: prescriptive standards provide methods of achieving objectives, while performance-based standards outline expectations for the desired outcomes Vierra (2016). To illustrate with energy consumption, prescriptive standards require using methods like efficient LEDs. In contrast, performance-based standards set a goal for energy deduction without specifying methods, allowing flexibility in solution.

GBCS emerged to establish standardized practices in construction, offering a common framework to evaluate and differentiate buildings that follow sustainability standards. Over time, these systems expanded to address not only environmental concerns but also social and economic, reflecting a broader understanding of sustainability as stated by Awadh (2017). While implementing these global standards locally, adjustments can be made according to local requirements. But yet, the overarching goal is to encourage and recognize practices that contribute to a holistic sustainability approach in building.

The Building Research Establishment Environmental Assessment Method (BREEAM) arose in the early 1990s as one of the first comprehensive green building certification systems in the United Kingdom. Following the success of BREEAM, other countries and regions established their own green building certification processes: LEED (Leadership in Energy and Environmental Design) in the United States, Green Star in Australia, and Estidama in the United Arab Emirates are a few examples which are extended their usage beyond the countries. All these initiatives have developed throughout time, adding social and economic aspects into their criteria to give a comprehensive approach to building sector sustainability Braulio-Gonzalo et al. (2022).

The functional benefits of green building begin with enhancing companies' competitiveness in the market. Tan et al. (2011) explored how green building certificates enhance contractors' competitiveness. The study revealed that "good corporate governance of environmental and social issues not only enhances companies' shareholder value but also safeguards their highly valuable reputations". It's crucial to emphasize that the advantages of these certificates go beyond contractors, benefiting all stakeholders at different levels. In addition to being a valuable marketing tool for developers, Vierra (2016) highlights the market desire for green building certification.

As mentioned, requirements of green building certification systems aren't universally applicable due to project dynamics, making one more suitable than another based on factors like location, budget, and goals. Selecting an appropriate certification system involves considering essential aspects such as cost, ease of submission, and building performance to determine the most relevant rating system and achievable certification level Vierra (2016). It's crucial to note that each green building certificate comes with distinct specifications, which may vary based on project requirements, whether for refurbishment, new construction, or specific needs. Obtaining green certification requires teamwork across various functions such as supply chain, planning, design, and manufacturing. Yet, the unique aspects of green construction and certification pose challenges, with cost as the main obstacle hindering broader adoption of these innovative practices, as highlighted by Agyekum et al. (2019).

Barriers to GBCS Adoption

Barriers to adopting sustainable practices exist across various dimensions, including economic, social, cultural, political, and systemic factors, as identified by Horner and Ryan (2019). Moreover, the type and intensity of these barriers vary among countries, contributing to distinctions in their quantity and severity Agyekum et al. (2019). Yet, it is essential to carefully analyze the requirements that provide guidance and an implementation plan for stakeholders. When examining current GBCS' characteristics, key requirements centered around energy efficiency, water preservation, minimum negative environmental impact, reliance on renewables and sustainable materials, and efficient space use.

Several studies have investigated the barriers hindering the widespread adoption of green building certificates. Fan and Wu (2020) identified obstacles as high upfront costs, limited access to capital, social and psychological barriers, and a lack of information, experience, and effective incentives. Another study by Karji et al. (2021) indicated common obstacles, including a lack of green building knowledge, high costs, insufficient incentives, lack of motivation, and insufficiency in policies and regulations. Similarly, Agyekum et al. (2019) highlighted various barriers highlighting regulatory deficiencies, inadequate training, developers' hesitation due to perceived additional costs, high investment cost barriers, and challenges in procurement and project-delivery mechanisms.

Considering local-level challenges, Shen et al. (2018) investigated barriers in Thailand using a Likert-scale survey among different stakeholders. The findings show social barriers, with the lack of owner motivation ranking as the major obstacle among all participants. Collectively, these studies underscore the multifaceted challenges impeding the widespread adoption of green building certificates, encompassing knowledge gaps, financial considerations, policy shortcomings, and social factors.

Furthermore, it is important to mention that traditional construction practices have been in place for many years. Transitioning from conventional to sustainable and digital methods will require significant time and changes across individual, organizational, and industry levels. For this reason, this transformation will not be without its hurdles Diyana et al. (2013) Li et al. (2019).

All stakeholders acknowledge the above-mentioned barriers, and as a response, various financial and non-financial incentive mechanisms have been introduced to motivate stakeholders. These incentives, typically offered by governmental entities, environmental agencies, and industry associations, are designed to encourage sustainable building practices and contribute to overarching sustainability objectives.

Incentive mechanism

An incentive mechanism is a structured strategy to encourage specific behaviors, actions, or outcomes by offering rewards or penalties. This concept has extensive application across several disciplines, leveraging components to drive individuals, organizations, or entities toward desired outcomes. In the context of green building, incentive mechanisms play a vital role in motivating developers to embrace sustainable construction Fan and Wu (2020). The eligibility of the incentive mechanism is mostly connected to the green building certification system because the incentive promoters are able to differentiate the project to award.

The Figure 1 illustrates the categorization of green building incentive mechanisms, highlighting their diverse nature and underscoring the necessity for a case-by-case approach. The literature created a spotlight on effectiveness. The reason for such a spotlight is that evaluating the efficiency of incentive mechanisms contributes valuable insights to understanding how different incentives influence stakeholders. The literature delves into the effectiveness of incentive mechanisms, often through case scenarios.

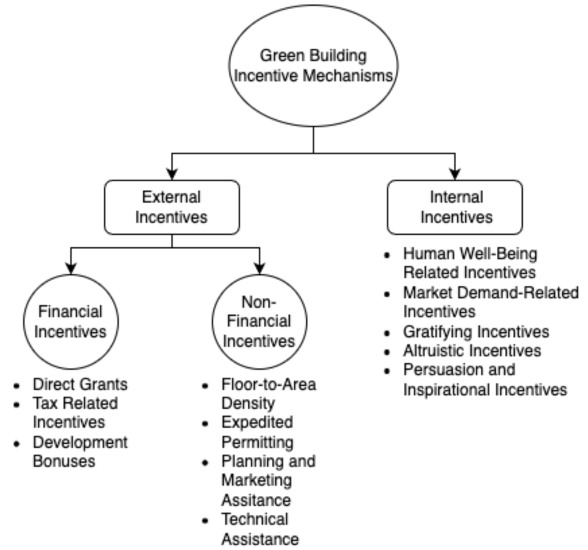

Figure 1: Categorization of Green Building Incentives adapted from Olubunmi et al. (2016)

The study conducted by Dounas et al. (2022) showcases the versatile usage of incentive mechanisms by proposing an innovative incentive model to reduce carbon and waste in the construction industry. It is highlighted that the proposed incentive model benefits environmental aspects and also enhances overall efficiency. Moreover, the research conducted by Sauer and Siddiqi (2009) compares the effectiveness of three different incentive mechanisms based on the production status offered by local government. By using regression analysis, the most preferred incentives are concluded as Gross Floor Area(GFA) concessions, administrative, and financial incentives. In another study, Agyekum et al. (2019) investigates the barriers to adoption in Ghana. The authors' findings show inadequate awareness of the benefits of green certification has the biggest impact on adoption in a developed country, Ghana. In a parallel study by Work (2007), the authors revealed that their findings point out that developers are aware of these incentives but don't always use them. The main reason is the timing of development decisions and the response time of local government don't always match together. Developers must take quick decisions, and governments prefer to move more slowly to see the outcomes.

Non-financial incentives have limited visibility in the literature compared to financial ones. Karji et al. (2021) connects this limitation to the poor impact of social incentives. Similar to the previously mentioned research, the root cause of the ineffectiveness of social incentives is the lack of information on the benefits of green building. It is possible to convey that recognition is elemental on non-financial incentives for governments and incentive receivers due to its ability to create public awareness.

On the other hand, Olubunmi et al. (2016) specifies weaknesses in the current green building incentive mechanisms, and in terms of the social effect of certificates, the authors criticize the close link between incentive mechanisms and third-party certification institutions due to the potential bias or inequity caused by economic relationship. Further criticisms of current green building incentive mechanisms are the lack of enforceability mechanisms, the absence of a mechanism to determine the optimal level and the non-transferability of incentives. But it is also mentioned that the production rate method gives limited information on real adoption rates therefore the outcomes are subject to discussion.

Fan and Wu (2020) conducted a cost-benefit analysis for incentive mechanism by using the Analytic Hierarchy Process. Based on outcomes, the authors proposed a hierarchy structure of cost and benefit criteria as actual and hidden. The high upfront cost of green building remains a major cost problem. Considering benefits, actual ones such as energy savings and GFA concession were deemed more important than hidden ones. However, it is crucial to note that stakeholders may not be aware of the proposed essence of hidden benefits like outdoor environment, productivity, and brand recognition, as mentioned, creating an opportunity for further research in the literature.

Considering the status of the construction industry, more adoption of green buildings is inevitably needed to increase sustainability performance. Incentive mechanisms play a vital on this as a main driver of stakeholder motivation. Research supports the feasibility of blockchain in incentive design, offering transparency and security to build stakeholder confidence. This decentralized and secure approach has the potential to generate economic benefits by cutting intermediaries, lowering transaction costs, and improving resource allocation within the incentive ecosystem, as stated by Fan and Wu (2020). Furthermore, side benefits due to the characteristics of blockchain may reveal new incentives and increase the overall effectiveness.

Blockchain

Definition and Basic Concept

Blockchain technology gained a reputation with the publication of "Bitcoin: A Peer-to-Peer Electronic Cash System" white-paper by an author under the name Satoshi Nakamoto Nakamoto and Bitcoin (2008). Fundamentally, blockchain is an unalterable distributed ledger allowing secure data transfer. Blockchain records data in groups on a peer-to-peer (P2P) network as detailed by Raj (2021). The name 'blockchain' is derived from two terms: 'block,' referring to the grouped data sets, and 'chain,' indicating that these data sets are securely linked using cryptographic principles.

In blockchain, transactions are a prominent feature that refers to an action that records the exchange of data or assets between parties. Once a transaction is completed, it leads to creating a new block with a time-stamp and linking to the preceding block to the end of the chain, as detailed by Natalia Maslova and CTP (2018). The information within each new block holds a secure, cryptographic summary of the one before it. This interconnectedness form enhances security naturally. Once data is added to the chain, it becomes immutable, making it impossible to alter or erase.

In a decentralized system like blockchain, consensus mechanisms are vital to ensure agreement among participants regarding transaction validity, thereby preventing system failures and keeping the whole system secure. Zhao et al. (2020) mentioned that besides security and continuity of the ecosystem, consensus mechanisms also significantly influence performance metrics such as scalability and block creation speed. In the consensus mechanism, the active participation of nodes in all roles is crucial to ensure system security, decentralization, and integrity Zhao et al. (2023). Roles and responsibilities within the ecosystem were outlined by Han et al. (2022) with broadcasting nodes participating in the verification, and spread of transaction records, while mining nodes actively execute the consensus mechanisms and support the block creation. Lastly, full nodes' responsibilities fall between the other 2 types.

It is important to highlight that executing consensus mechanisms comes with a cost, therefore, participants need to be compensated to maintain system continuity. Additionally, participants often prioritize actions that serve their own interests. In response to this challenge, incentive mechanisms are introduced to motivate cooperative behavior and maintain the security of the decentralized system, as elaborated further.

As we move towards the Blockchain 4.0 era, blockchain applications aim to enhance user experience and speed for creating advanced decentralized applications for all sectors. While blockchain technology has demonstrated transformative potential within the construction sector, its specific implications for green building certification systems warrant further investigation.

Blockchain Applications

Blockchain technology is widely adopted across numerous sectors, demonstrating its potential to transform traditional processes, promote sustainability, enhance effectiveness, and drive innovation. The finance sector was among the first to embrace blockchain technology, but its applications extend to sectors rapidly such as construction, energy, crowdsensing, and supply chain management, as detailed by Xu et al. (2017).

For instance Zhang et al. (2020) proposes a blockchain-based certification system to address inefficiencies regarding to centralization in China's renewable energy certificate process, emphasizing intelligent and automated processes facilitated by blockchain technology. The studies conducted by Marques et al. (2023) Delardas and Giannos (2023) also delve into the application of blockchain in the energy sector, aiming to enhance efficiency and effectiveness. The research conducted by Wei et al. (2020) explores decentralized crowdsensing architectures via blockchain, focusing on security enhancement, privacy protection, and incentivization mechanisms. Simulation of the proposed model confirms its feasibility, showing that the proposed incentive mechanism effectively encourages participation.

The research conducted by Wei et al. (2023) focuses on addressing technical information exchange barriers in the supply chain, which lead to substantial energy consumption. By leveraging blockchain for data management and government incentives, the paper investigates strategies to improve the sustainability of supply chains. The research proposes practical measures and introduces a data governance platform to foster eco-friendly supply chains, drawing insights from government involvement and behavioral theories.

In the built environment, distributed ledger technology offers promising applications across several domains. Li et al. (2019) categorized these domains as smart energy, smart cities and the sharing economy, smart government, smart homes, smart transport, Building Information Modelling (BIM) and construction management, and innovation in business models and organizational structures. The majority of the cited articles in this paper discuss the application of blockchain technology in the various domains of built environment. Also, studies like Smajgl and Schweik (2022) bring a further looking perspective and anticipate that blockchain technology will bring significant changes into the existing socio-economic framework, influencing the governance aspects and expanding the boundaries of solutions created in sustainability.

While numerous studies demonstrate the advantages of blockchain technology across different domains, its specific application in green building certification systems remains relatively unexplored. Understanding the governance and design principles of blockchain applications is crucial, particularly within green building certification systems, where tailored approaches are needed to address adoption and sustainability challenges effectively. The following chapter will delve into the governance and design considerations specific to blockchain technology in the context of green building certification, underscoring the dynamic and versatile nature of blockchain technology in diverse contexts.

Blockchain Governance and Design

The close connection between blockchain governance and its design arises from the foundational principles of technology. Design encompasses the underlying architecture, consensus mechanisms, and smart contracts that shape how the system operates. These design choices directly influence how governance is implemented within the blockchain network. Governance rules are often encoded in smart contracts, automating and enforcing predefined rules without the need for centralized control. As mentioned before these choices and rules also determine performance, including scalability, efficiency, etc. of the application, as further detailed in Han et al. (2022).

De Filippi et al. (2020) emphasizes that blockchain governance relies heavily on incentives coded into the protocol and game-theoretic principles align with community priorities. The goal of good governance is to align diverse stakeholders toward a common understanding and agreement. Effective governance can increase the reliability and overall success of domain by ensuring that created financial and non-financial incentives match desired behaviors and encouraging community adherence to shared standards.

Therefore, introducing blockchain into a specific domain requires a deep understanding of both design principles and governance requirements to achieve effective application. A holistic approach is essential to ensure that the blockchain solution aligns with the required outcome and goals of the application.

Blockchain Related Incentive Mechanisms

Incentives are vital in blockchain systems to motivate participants and align their interests with the collective goals of the system. Incentives support positive behavior, discourage malicious activities, and foster an active and engaged community within the decentralized networks. Well-designed incentive mechanisms not only drive the desired behavior but also play a pivotal role in shaping the governance structures that govern the decision-making processes of the blockchain protocol. Thanks to the inherited features of blockchain, participants can be motivated in several forms of incentives.

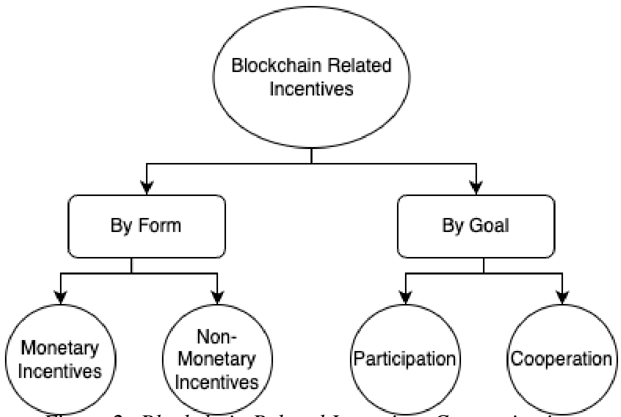

Figure 2: Blockchain Related Incentives Categorization, adapted from Han et al. (2022)

The Figure 2 illustrates the high-level classification of blockchain-related incentives based on the form and goal of the incentives in the literature. Monetary incentives are designed to regulate system entities economically, motivating participation with financial rewards. Non-monetary incentives, like credit-based and reputation-based systems, foster trust among entities, while gamified incentives leverage individuals' preferences for enjoyable experiences to guide their behavior within the system. Tokens and badges are commonly used in gamified mechanisms as incentives for system engagement as ticket.

In terms of goals, incentive mechanisms can be categorized as encouraging participation to maintain system sustainability and promoting cooperation among entities. The participation goal addresses nodes' selfish nature by providing incentives for their involvement, which is crucial for ensuring security and decentralization. On the other hand, the cooperation goal acknowledges the fact that selfish nodes may deviate from system design, posing threats to the system. To mitigate, introducing incentive mechanisms becomes essential, fostering cooperation through adherence to system protocols and discouragement from initiating attacks.

In conclusion, the multifaceted nature of blockchain, with its diverse array of incentive mechanisms, creates opportunities for various benefits within the ecosystem. By strategically aligning incentives with the goals and form, blockchain not only addresses the rational and profit-driven behavior of nodes but also promotes the safety, sustainability, and decentralization of the system. In essence, blockchain's innovative approach to incentives unlocks opportunities, driving positive contributions and reinforcing the resilience of various domains implemented.

Blockchain for GBCS

There is a growing need for a more comprehensive and digital green building certification system to address the challenge of inadequate motivations hindering widespread adoption. Blockchain, with its inherited features, has the potential to bring more integrity to certification practices. By leveraging its capabilities, blockchain has the potential to bolster the credibility of certificates while streamlining verification procedures.

Blockchain has been already implemented as a transformative factor in certification processes, providing a streamlined and reliable method to verify accomplishments. Fowler (2017) suggests that blockchain integration in certification processes holds promise for lowering costs associated with advancement in measurement methodologies to meet evolving quality standards. In the article by Woo et al. (2020), the authors support the idea of blockchain-enabled GBCS and target the high cost associated with the current systems. Their research proposes a blockchain-based framework for measurement, reporting, and verification as a cost-effective alternative.

Pu and Lam (2023) discuss the advantages of blockchain-enabled certification systems and highlights that GBCS is a particularly suitable domain to apply. Firstly, blockchain's ownership or identity management capabilities provide a secure way to verify the identity of individuals or entities involved in green building projects. Secondly, the provenance tracing capacities of blockchain ensure transparency in the supply chain, allowing stakeholders to trace the origin of materials used in construction. Lastly, ownership transfer mechanisms can streamline the transfer of green building certifications between different parties, enhancing overall efficiency in the certification ecosystem.

Introducing blockchain into the GBCS may enhance the certification system by providing both monetary and non-monetary benefits. Therefore, stakeholder dynamics play a vital role in blockchain design, particularly for incentive mechanisms and their effectiveness. Each stakeholder in the green building certification process has unique priorities and motivations as detailed in Mulligan et al. (2014). Building owners seek cost reduction and streamlined processes, while architects focus on sustainable building design principles. Certifying bodies prioritize integrity and credibility through incentive mechanisms. Regulatory bodies may enforce compliance with incentive requirements or promote adoption by implementing new incentives, depending on the ecosystem dynamics.

Dynamic Alliances, as described by Grover et al. (2021), refer to collaborations formed by entities with mutual interests and goals in a given domain. Dynamic Alliances aim to create a collaborative environment that allows parties to leverage strengths, optimize resources, and accomplish common objectives. The authors suggest that integrating blockchain into governance ecosystems of dynamic alliances would bring notable benefits. Integrated Project Delivery (IPD), a project management approach tailored to the construction industry, has governance characteristics and principles that resonate with Dynamic Alliances. In this context, the research by Hunhevicz et al. (2022) proposes using blockchain for IPD using in a common pool resources scenario. Likewise, the authors suggest that blockchain implementation will leverage the governance of the domain. This suggests that the governance structures and incentive mechanisms inherent in blockchain implementation can effectively align with the principles of collaboration, trust, and accountability within green building certification systems.

In conclusion, the alignment of blockchain's governance with those observed in Dynamic Alliances and IPD highlights the importance of carefully balancing stakeholder interests in design and governance decisions. Tailoring design and governance decisions to the diverse motivations of stakeholders ensures that incentive mechanisms effectively encourage collaboration, trust, and accountability within the green building certification ecosystem. In the context of GBCS, blockchain implementation can optimize collaboration, streamline processes, and foster innovation, thereby advancing sustainability goals within the construction industry.

Conclusion and Future Work

In overview, the construction industry encounters challenges including issues with information exchange, materials procurement, high costs, and trust, limiting its ability to achieve better sustainability performance. Blockchain technology holds promise in addressing these challenges by its decentralized and secure nature. Our literature review acknowledges the potential of blockchain in the construction industry to enhance sustainability performance. However, practical implementations are currently constrained, indicating a gap between theoretical recognition and widespread adoption.

To address this gap, we propose a comprehensive survey targeting diverse stakeholders involved in green building certification. This survey aims to explore stakeholders' motivations to participate in GBCS and assess their receptiveness to various incentive mechanisms and receptivity toward blockchain. The survey results are expected to close the gap between theoretical discussions and practical implementations of blockchain in green building certification. Also, these findings may support decision-making processes, driving refinements in certification practices toward greater sustainability.

Throughout the literature review, it is identified that the integration of blockchain technology promises to enhance transparency, efficiency, and trust in certification processes. Moreover, such a system has the potential to create a range of diverse incentives, including both financial and non-financial, which may be novel to the construction sector. In light of survey findings, this integration holds promise for promoting the adoption rates of GBCS by tailoring design and governance preferences to stakeholders. In conclusion, while the potential benefits of blockchain for GBCS are recognized, the dynamics of GBCS need to be thoroughly comprehended. The identified literature gap calls for a survey with GBCS stakeholders to investigate their motivations and preferred incentives. The outcomes of such a survey inform the governance and design choices of the best-suited blockchain technology for widespread adoption in green building certification.

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