What is the potential value of tokens and token engineering for the architecture, engineering, and construction industry? A positional paper

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WHAT IS THE POTENTIAL VALUE OF TOKENS AND TOKEN ENGINEERING FOR THE ARCHITECTURE, ENGINEERING, AND CONSTRUCTION INDUSTRY? A POSITIONAL PAPER

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Abstract

What is the value of tokens for blockchain applications in Architecture, Engineering, and Construction (AEC)? How can token engineering be contextualized in AEC? This positional paper instigates the tackling of these largely unexplored questions. Following a literature review and a visiting of token engineering fundamentals, the paper's position is that tokens can indeed hold potential value for AEC. This value can be direct, utilitarian, security-related, and/or pegged, and reflected in technical and economic terms. For this value to be realized, the token must be systematically embedded in the AEC ecosystem – therefore dependent on sociotechnical parameters in AEC.

Introduction

Tokenization, in technical terms, refers to the process of converting a piece of data into a random string of characters known as a token (Li et al., 2019c). The process protects sensitive data by substituting it with non-sensitive data (Morrow and Zarrebini, 2019). Tokens only point to the original data, having no mathematical relationship to the real data they represent (Morrow and Zarrebini, 2019). Tokenization is one of the applications of blockchain that allows users to digitize tangible and intangible assets, where each blockchain token represents a certain share of the asset ownership (Tian et al., 2020). Blockchain tokens are commonly categorized into utility and security tokens. Utility tokens are issued through "Initial Coin Offerings" (ICOs) (Chohan, 2019), a process in which issuers sell tokens in exchange for cryptocurrencies (e.g., Ethereum) for crowdfunding (Dounas et al., 2022). Utility tokens grant their owners access to tangible products or services that are offered by the issuing company (Dounas et al., 2022). By contrast, security tokens are generated through "Security Token Offerings" (STOs) and they must comply with securities rules and have to be backed by financial assets, such as equities or fixed income (Dounas et al., 2022). Tokens can be also used for payment purposes (e.g., stablecoins as pegged cryptocurrencies) (Tian et al., 2020).

In that context, tokens are digital assets that operate as elements of smart contracts (i.e., computer protocols facilitating, verifying, or enforcing terms and clauses (Cuccuru, 2017) on top of a blockchain infrastructure. They are used to carry value, making them useful instruments in peer-to-peer (P2P) economies (Laurent et al., 2018). This can open new opportunities in practice for decentralized applications and a "tokenized economy", where tangible and intangible assets can be exchanged through greater liquidity, accessibility, transparency, and faster and cost-effective transactions (Laurent et al., 2018). Tokenized data also enables greater data compartmentalization and portability, where sensitive data can only be accessed by the holder of the correct token (Morrow and Zarrebini, 2019). With that functionality, tokens have been used in blockchain infrastructures in several industries – e.g., supply chain management (Varnavskiy et al., 2018), investment financing (Tian et al., 2020), asset and property ownership and management (Konashevych, 2020), and personal/organizational data management (Liu, 2016).

However, the use of tokens in the Architecture, Engineering, and Construction (AEC) industry, has been minimal, with most cases revolving around pilots and prototypes largely taking after the examples of other industries. The question then is pending; is there a value in using a token for blockchain applications in AEC – and what is it? In an AEC-contextualized blockchain ecosystem, "tokenizing" implies the conversion of digital or physical assets related to the built environment into tokens, or the process of using tokens to encapsulate value. This in turn gives rise to another question: How could tokens be designed for relevant applications, i.e., how can token engineering (Zhang et al., 2020) be contextualized in AEC? In this positional paper, we attempt to initiate the tackling of these two questions, thus stirring the interest for this nascent field.

After this introduction, the study's research method is described. Then, its background (in the form of a literature review) and conducted analysis are expounded, the paper's position is postulated, and it concludes with some final remarks.

Research method

This paper builds on a background, then develops an initial sketch of a framework for considering the implications of answering the stated research questions, and finally synthesizes its material to form its position.

The background of this study concerns the (very limited) state-of-research (and -art) on tokenization in AEC. It is based on a concept-centric literature review enhanced by units of analysis that was conducted in iterations (Webster and Watson, 2002). The main searched concepts were "blockchain", "tokens", "token engineering", "AEC", and "built environment". The emerged units of analysis included, indicatively, "decentralized market structures", "fungible" and "non-fungible". Finally, exclusion and inclusion criteria (e.g., contextual relevance) were applied on the found sources, for finally developing the ones featured in the current study (Dundar and Fleeman, 2017).

Finally, synthesizing the literature results into the positioning of this paper against the stated research questions is done using the abduction method, where we worked iteratively between literature, theory, and data (Bell et al, 2019) – in this case, data as research units.

Literature review

The development, utility, implementation, and potential benefits of tokens in the context of the AEC industry, through the application of contextually relevant blockchain systems, is an emerging research topic. Most significant studies elaborating on tokenization for AEC trace back to 2019 – which is hereby used as the starting point for our review. The reviewed studies are organized along two themes: the ones referred to as "conjectural" studies that hypothesize on tokenization for AEC, sometimes looking into examples from other industries; and studies that elaborate more specifically on conceptualizing or developing token prototypes for AEC.

When it comes to the conjectural studies hypothesizing on the potential of tokenization for AEC, Li et al. (2019a,b) had initially postulated that asset tokenization (crowd-sale smart-contract) can initiate decentralized fund-raising events, where tokens are delivered and can signify any virtual asset (e.g., shares, bonds, entitlements for investment or donation). On top of that, Maciel (2020) briefly mentioned that asset tokenization can be an emerging potential application of blockchain into real estate, while Hunhevicz et al. (2022a) considered that new, tokenized economic systems in AEC, as well as increasing tokenization, can lead to decentralized market structures for trading and exchanging assets directly between project participants or across projects. Along this thread, Hunhevicz and Hall (2020) mentioned that smart contracts can enable the automation of business logic for assets and data managed on the blockchain, and the creation of new types of tokenized digital assets, while Konashevych (2020) envisioned an asset token for the AEC as being connected with its cadastral data (geo-data) and property rights, including leases, mortgages, superficies, and other encumbrances and liens. It is mentioned that the connection of title records with real estate and property rights is ensured by relevant blockchain records held by trusted third parties with the authority to certify ownership, deeds, and other transactions with property rights (Konashevych 2020). Tokenization for the real estate is furtherly investigated in Chow and Tan (2021), by mentioning nascent platforms like BrickX, KASA, ADDX, and Minterest having successfully launched real estate tokens in Australia, South Korea, and Singapore, respectively. Chow and Tan (2021) then alluded to tokenization being a viable funding source for the relatively poorly capitalized financial markets (esp. in the Asia-pacific region). Real estate tokenization was also the context for Plevris et al.'s (2022) study, where they identified it as the process of creating a digital asset that represents a property on the blockchain. This process can address various challenges in capital formation and liquidity, although it requires a legal wrapper around the property to secure it, as well as create an investment vehicle (Plevris et al., 2022). Moreover, tokenization of business processes and value may lead to new business models for managing projects – e.g., offering token-based incentives when project supply partners provide correct and timely maintenance data (Tezel et al., 2020). Involving the users, Tezel et al. (2021,2022), Elbashbishy et al. (2022), and Gurgun et al. (2022) have proposed turning a tangible or intangible asset into a digital token for crowdfunding, allowing the associated ownership and transactions to be recorded on a blockchain – tokenizing assets can then help simplify fundraising (esp. for start-ups, SMEs, or Decentralized Autonomous Organizations (DAOs)). Tokens (incl. NFTs) and crypto-assets can be key for the implementation of iContracts (intelligent contracts) (McNamara and Sepasgoza, 2021), as well as used for property and asset development and acquisition (Mistrangelo et al., 2022). Moving to construction supply chains and logistics, Kifokeris and Koch (2022) mentioned that crypto-assets and NFTs can enhance both the granularity and the atomicity of the integration between the monetary and material flows in construction supply chains, and Sadeghi et al. (2022) envisioned the application of tokens in reverse into logistics and the supply chain to incentivize loyal customers to return end-of-life products to the construction product manufacturer. Finally, Tian et al. (2020, 2022) attempted an analysis on existing crypto-assets as templates for tokens for the AEC. Specifically, Tian et al. (2020) analyzed ZiyenCoin, the first SEC-compliant energy asset security token, from the perspective of the key participants, relevant regulations, and token offering procedures. Results showed that tokenization can improve infrastructure assets liquidity, transaction efficiency, and transparency across intermediaries (Tian et al. 2020). Then, Tian et al. (2022) explored the potential of blockchain-enabled asset tokenization to create a new economic model to integrate non-financial values (e.g., positive social and environmental impacts), into tradable cryptographic tokens. ZiyenCoin, SolarCoin and WePower Token, were exemplified as tokens in infrastructural development.

The studies targeted conceptualizing and/or developing prototypes of tokens for AEC are far fewer than the conjectural studies above – however, they do show that the relevant research becomes more contextually specific. Lu et al. (2021) have shown that construction asset tokenization can be part of deterministic smart contracts that can be independently executed in the blockchain without interaction with the external world. Scott et al. (2022) have described the Project Bank Account (PBA) Blockchain Model for potentially providing liquidity in the case of non-payment by the client, through a blockchain-based tokenised securities service provided by a financial institution. A financial provider (e.g., a bank) can potentially supply project finance in exchange for the client's tokenised collateral – also in the context of the AEC (Scott et al., 2022). Teisserenc and Sepasgozar (2022) considered blockchain-based digital twins (BCDTs) for construction projects leveraging NFTs to tokenize value into digital assets that could be transferred on the blockchain. Hence, datasets specific to BCDTs could be turned into non-fungible tokens (NFTs, denoting a unique digital asset or physical entity) enabling the transfer of ownership and traded on digital marketplaces (Teisserenc and Sepasgozar, 2022). In architectural design, Dounas et al. (2021) have shown that topology graphs organize NFTs corresponding to building components and/or the building itself. Dounas et al. (2022) have then conceptualized that smart contracts and tokenization, can act as a stigmergic information layer for creating collective digital factories in construction. Token types can then be encoded within smart contracts and used as proxies for the value and functionality of cyber-physical systems: Utility tokens for accessing functionality; security tokens for representing an asset's value; and payment tokens for transactions (Dounas et al., 2022). All these can either be fungible (interchangeable with each other) or NFTs (Dounas et al., 2022).

Token engineering for the AEC industry

Underlying principles

Based on the previously expounded background, as well as sources that will be elaborated on in the following, we can extract two principles for token engineering for AEC.

The first principle revolves around resolving the causal relationship of the reason one would need a token in AEC. Hunhevicz and Hall (2020) have described in detail the premises under which one would need a blockchain in construction and explain the underlying crypto-economic design that certain use cases should have. Those use cases oscillate between economic (i.e., coins/tokens as disbursement or incentive scheme automation of payments and contract deliverables) and technical (i.e., automating the digital and data infrastructure of the AEC industry though decentralised apps or DAOs) (Hunhevicz and Hall, 2020). Through this analysis, we can postulate the principle of duality of the role a blockchain, and, consequently, a token can have: technical (i.e., automation of the infrastructure), and economic (i.e., the structuring of incentives and disincentives). This duality can reflected in, e.g., blockchain/tokens inducing technology-based trust and collaboration in construction transactions, denoting a contractor's job completion or economic liquidity (for reducing the client's need for due diligence, affecting the decision on contract type, or reducing performance bond risks.

This first principle (token duality) helps us understand the way a token can hold value through its function. There are specific methods with which this happens (Tan 2020):

- Holding direct value as a payment mechanism.
- Holding utilitarian value (e.g., governance of a system, or automating certain parts of infrastructure).
- Holding security value, i.e., representing another object or accumulation of value that exists outside the blockchain (e.g., physical objects or company stocks).
- Holding pegged value, e.g., acting as a stablecoin. Stablecoins are cryptocurrencies holding value that is "pegged" (i.e., tied), to that held by another currency (fiat or not), commodity, or financial instrument (Lyons and Viswanath-Natraj, 2023).

Following this, the second principle for token engineering for AEC concerns not the artefact (i.e., the token), but the contextualization of the process of tokenization itself. As such, the function of token engineering within crypto-economics has been described as the design of incentives (and/or disincentives), to change or guarantee particular behaviours – all through the use of the advanced technical security of cryptography, immutability and automation provided by blockchain systems (Tan, 2020). The primary function of the token within economic design of a crypto-economic system is then to capture value accrued within an ecosystem (Tan, 2020). This description can help us postulate the second principle for token engineering for AEC, namely the need of token engineering to ensure that, through the development of tokens, there is a contextual capture of value accrued within the AEC, thus reflecting the existing – and building a new – ecosystem. Tokens do not exist in a vacuum but are the building blocks of a sociotechnical cyberphysical crypto-economic system.

This second principle of token ecosystemic embeddedness, builds on the principle of duality, in that it expands on the four methods with which a token can hold value, by contextually framing such held value as it accrues from – and contributes to – the AEC ecosystem. This means that token engineering must consider the sociotechnical parameters pertaining to AEC – such as its project-based nature, the multitude of sciences and trades involved, the types of contractual and other relationships between stakeholders (who are envisioned to transact with tokens), the level of existent digital infrastructure, the impact of economical fluctuations on the sector.

Those two principles are envisioned to feed into each other in the process of token engineering for AEC, also reflecting another level of qualitative abduction. They can then contribute their different components to the intended value of a token in a "funneling" way. Fig. 1 (see next page) offers a schematic representation of this conception.

Phases and methods of token engineering for AEC

The process for token engineering covers the discovery phase, the design phase, and the deployment phase (Penland et al., 2022) – see Fig. 2 (see next page). Here, we briefly describe the fundamentals of each phase, the mathematical simulation of a token's performance and the agents' desired behavior within an ecosystem (when applicable) (Penland et al., 2022), and possible reflections of those elements in AEC (so that the principle of contextual embeddedness is not violated).

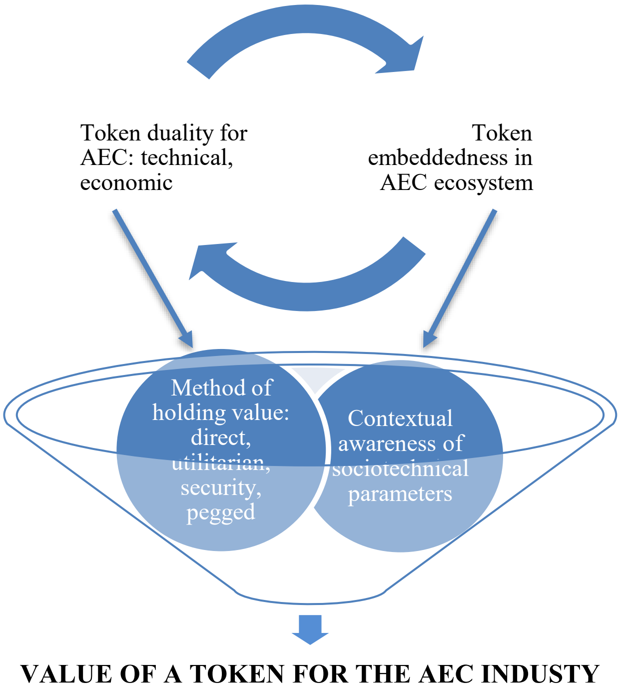

Figure 1: Concept of principles of token engineering for AEC: definition, relationship, and contribution to a token's intended value

Discovery phase

The discovery phase consists of defining the system goals, identifying the potential stakeholders, and mapping the ecosystem within which the token will operate (McConaghy, 2022). For example, Hunhevicz et al. (2022) have determined dimensions to be explored in a common pool resource (CPR) scenario for the governance of collaborative construction project deliveries.

From these, system requirements can be developed along an analysis determining where the related stakeholders would find value (McConaghy, 2022). A tool supporting this process would be an ecosystem motivation matrix that encapsulates the incentive structure, along with a list of metrics definition (McConaghy, 2022).

The success of the token(s) can thus be measured against criteria set in the discovery phase, and the stakeholders' requirements quantified (e.g., the clients' quality specifications for the as-built object). Other tools could organize, define, and interconnect system variables – e.g., causal loops, stock-and-flow diagrams, and block-diagrams.

Design phase

This phase consists of determining the algebraic functions that describe the system state as captured in the discovery phase (Dounas, 2022). These functions are determined by the type of system and the design patterns one develops (McConaghy, 2022). For example, automated market makers for decentralized financing can use a weighted constant product maker in the form of $aX * bY = K$, where K is the invariable constant of the liquidity provided, X is the number of token X, Y the number of token Y, and α and b their respective weights. This determines a parabolic curve that governs the exchange between the two tokens (McConaghy, 2022).

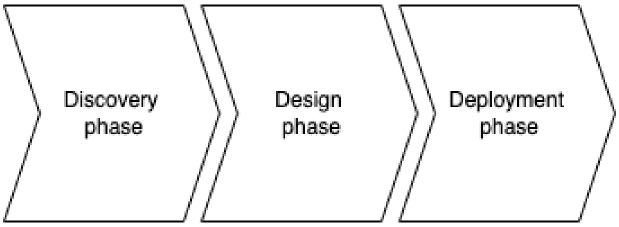

Figure 2: Phases of token engineering

However, in many cases in AEC, we might not design an automated market maker, but an automation system that includes a token. Examples can include the determination of a dataset's completeness for Building Information Modelling (BIM), or whether a building component is a NFT that can be traded in a market or create the infrastructure for a circular economy. As such, token engineering within AEC does not restrict itself only to economic models but needs to consider and be compatible with an ever-increasing array of digital and physical technologies comprising the AEC cyberphysical systems.

Deployment phase

The token's technical implementation takes place here – incl. developing smart contracts and the appropriate blockchain topology (Dounas, 2022). The system is offered to the stakeholders, first on a test network, then in a live environment (Dounas, 2022). The utility and governance of the blockchain (and the tokens deployed within it) are ascertained.

At the same time, testing processes can be implemented on the systemic level, entailing testing the blockchain features, gathering user feedback, and monitoring the blockchain's functions (McConaghy, 2022). This systemic level reflects the blockchain topology, and, in turn, the context of the tokens. For example, permissioned blockchains are considered preferable in construction supply chain and logistics (Kifokeris and Koch, 2022).

After successfully testing it, the system goes through the evaluation phase to identify crucial problems and potential improvements (McConaghy, 2022). Ideally, this is a continuous improvement process.

Distinction of crypto-economics vs token engineering and elements of a new political economy for AEC

Crypto-economics refers to the functionality of a blockchain network (Dounas, 2022). However, as stated before, token engineering for AEC requires that we understand computing in the industry and the built environment as a cyberphysical system, combining the properties of physical and computer engineering. This can be challenging, as concepts in either engineering type are not necessarily compatible with one another.

Token models in crypto-economics have been developed to optimise an automated market towards stability (Fritsch et al., 2021; Clark et al., 2022; Zargham and Shorish, 2022). Token design is modelled as a game where state-pace variables evolve in time according to differential equations that govern the tokens' performance (Zargham et al., 2021). In these models, decentralisation is understood as a computing property for censorship resistance (Brekke, 2020). Economic incentives are thus introduced in blockchains to make centralised business models based on surveillance and control unfeasible through the technical and economic design of the token model (Brekke 2020). However, decentralisation in AEC has a physical and geographical dimension (Zargham et al., 2021). Dounas (2022) has framed it in the autonomy of local economies – i.e., as a planning instrument and a political stance of geographically distributing power and resources in, e.g., urban planning. Thus, decentralisation, and the computing models that allow it, become critical in determining a new political economy for AEC. However, this political economy is not based on neoliberalism, but rather on mutualism and ideas of the commons (Token Engineering Commons 2022). Hence, on the protocol level, tokens can be rewards for maintaining the blockchain's common infrastructure. On the industrial level this might mean that tokens encapsulate incentives for the creation and maintenance of common infrastructure (e.g., digital building logbooks in AEC).

Position: why have tokens in AEC?

Given our analysis, we can now state our position against this study's two interconnected research questions:

- Tokens can *potentially* hold value for AEC, which can be direct (e.g., payments), utilitarian (e.g., in governance), security-related (e.g., in object representation), and/or pegged (e.g., as a stablecoin). This value can be reflected both technically (i.e., automating infrastructure), and economically (i.e., structuring incentives and disincentives). For this value to be realized, the token must be systematically embedded in the relevant AEC ecosystem.
- Token engineering can be contextualized in AEC by being aware of AEC-specific sociotechnical parameters throughout all its processes. Such parameters may have to do with the AEC-specific existing cyberphysical infrastructure, or even the business (e.g., contract types) or the institutional levels (e.g., construction labor market).

Our position can be followed by questions. Among others, an emergent one is: Even if there *is* value in deploying and using tokens for AEC, is that value significant enough to attract the interest of AEC stakeholders, as well as justify changes in established work practices and any investments required? A further elaboration on this response is beyond the scope of this positional paper and is left as a recommendation for future work.

Moreover, once one ascertains the need of using blockchain in their construction project based on, e.g., a need for decentralizing data exchange during production, how does one decide one how many and what types of tokens they need? In that case, a contextual approach to token engineering for AEC might require breaking down project processes in terms of governance, economy, and technical utility. This break-down analysis would likely have to be done quite early in the project lifecycle (possibly even during the feasibility study) and reflect decisions on token design. Designing tokens in itself is not an easy feat; it must be ensured that they bring about a truly sought-after decentralization and cyber-security that is meaningful in the context of AEC.

Furthermore, most of the token engineering discussion revolves around automated market making – but as explained before, there is a need to present the equivalent for decentralized apps for, specifically, AEC. Would this be driven by a neoliberal understanding of a zero-sum game where the egoistic maximization of value amongst purely competitive agents is the sole goal? This seems to be in tension with decentralization. Or some of kind of equilibrium enter the token engineering process, so that decentralization is coupled with collaborative (non-zero-sum optimized) value maximization amongst the stakeholders and/or interested parties? This is yet another question that we leave open for future investigation.

Conclusions

Tokenization is, technically, the conversion of data into random strings of characters known as a tokens. Practically, tokens are digital assets operating as elements of smart contracts on top of a blockchain infrastructure. They can carry value and thus be used in peer-to-peer economies and decentralized applications, where tangible and intangible assets can be exchanged through greater liquidity, accessibility, transparency, and faster and cost-effective transactions. Tokenized data can also enable greater data compartmentalization and portability, where sensitive data can only be accessed by the correct token holder. As such, this paper sets out to position itself against what the value (if any) of using a token for relevant blockchain applications in the Architecture, Engineering, and Construction (AEC) industry is, and how can token engineering be contextualized in AEC.

Through an analysis of the (nascent) relevant literature and elements of token engineering (underlying principles such as token duality and contextual embeddedness, the discovery, design, and deployments phases of the token engineering process, and the distinction of crypto-economics vs token engineering), the current position of this paper is that tokens can potentially hold value for AEC. This value can be direct (e.g., payments), utilitarian (e.g., in governance), security-related (e.g., in object representation), and/or pegged (e.g., as a stablecoin), and can be reflected both in technical (i.e., automation of the infrastructure), and economic (i.e., the structuring of incentives and disincentives) terms. For this value to be realized, the token must be systematically embedded in the relevant AEC ecosystem. The contextualization of token engineering for the AEC should entail an awareness of AEC-specific sociotechnical parameters relevant to the existing cyberphysical infrastructure, or be on higher levels (business, institutional).

This paper is limited by not including an empirical analysis challenging its postulations. However, given the nascency of this field for AEC, such an analysis is left as a recommendation for future work.

Other recommendations include a classification of tokenization opportunities by thematic area (e.g., sustainable development, circularity), as well as the associated benefits, challenges, and issues, opportunities. Moreover, open inquiries concern the significance of a token for an AEC application (even if an initial notion of value is accepted) and elaborating on how token deployment in AEC can help in a decentralized ecosystem that aligns with a collaborative maximization of value.

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