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The potential of adopting Blockchain Technology with BIM Implementations in the Construction Industry Ecosystem –A Review Paper

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ABSTRACT

Building Information Model (BIM) has been a mainstream concept within the Construction Industry for more than a decade. Countries are creating BIM Strategies to increase the performance of the industry as well as the governance, maturity and transparency. However, the industry has been known for its very dynamic ecosystem and a large number of dispute areas that make information validity very crucial as a key stone for any transformational initiative. Blockchain, on the other hand, has been famous since introduced in 2008 with the promise of creating new norms within the Digital Economy, and unlocking the potential of other technologies and business models in many industries, however, it still in the very early stages of implementation and maturity in the industry. This paper reviews the potential of adopting Blockchain Technology with BIM concepts in the built environment. It defines the technology and review its key value proposition from BIM perspectives.

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Introduction

BIM has been of significant benefits on many aspects of the construction industry such as collective design intentions understanding, conflicts reduction, quality improvement, faster and predictable cost management (Yang and Chou, 2019). Many countries created implementation strategies (Smith, 2014) and UK put a mandate for BIM Level 2 adoption on public projects (Eynon, 2016) believing that adopting BIM collaborative environments and technologies is essential in cost saving, adding to that the effort of the European Union moving towards BIM Level 3 (Eynon, 2016) which entails full collaborative process, and one of the pillars of their long term strategy is fostering digital ecosystem and infrastructure from regulation and physical perspectives, to support collaboration and trust.

However, from process perspectives, BIM implementations faces obstacles, such as, preserving BIM model historical modifications log (Kerosuo et al., 2015), real time collaboration and integration for co-design, interoperability difficulties resulting from the lack of standard communication specifications for BIM models sharing, and exposure to data leakage or manipulation (Nawari and Ravindran, 2019a), tracing liabilities and responsibilities, and preserving IP rights and privacy (Turk and Klinc, 2017). Moreover, the information output and timelines, permissions for model modifications, and how all of this can be governed contractually to support the BIM process was of question (Mcadam, 2010).

From legal perspectives, there is a lack of legal frameworks that detail model information and data ownership as well as contractual aspects (Ahn, Kwak and Suk, 2016). Responsibilities and rights clarity, also the ownership of model information and the protection of IPR was the most issue mentioned by researchers (Fan et al., 2018).

On the ICT side, there was the question back then whether project's participant should use the same BIM environment or not (Mcadam, 2010), if not, how reliable will be the interoperability between different BIM software, and the reliability of each individual ones, and how the software limitation can be put in the supply agreement. Apparently, the same question remains as (Fan et al., 2018) identified BIM and procurement systems incompatibility among the issues mentioned in research papers.

This paper explores the potential of adopting blockchain technology in combination with BIM implementations in the construction industry ecosystem. The paper provides a review of the literature on the potential benefits of adopting blockchain in construction, and discusses the potential impact of this technology on the various stakeholders in the construction industry. Approaching the discussion from three angels of technical, process and legal perspectives, it will use BIM and Blockchain interoperability along with the main Blockchain characteristics of Transparency, Traceability and Collaboration to discuss the Blockchain technology potential.

What is Blockchain

From technical perspectives, it is a tamper-proof digital ledger of transactions that records anything of value (Tamang, 2019). It is signed cryptographically, and all transactions are irrevocable and shared among all the participants in a Blockchain network (Gartner Inc., 2020). The focus here is on the fundamental difference in the technology usage for creating an "immutable database" with "multiple data writers" who normally have no "trust" among each other in a construction project value chain because of to the nature of the business. From a Business Perspective, Blockchain can be considered as a business audit trail, anything recorded between participants who have mutual agreement is validated, indisputable and immutable from any manipulation.

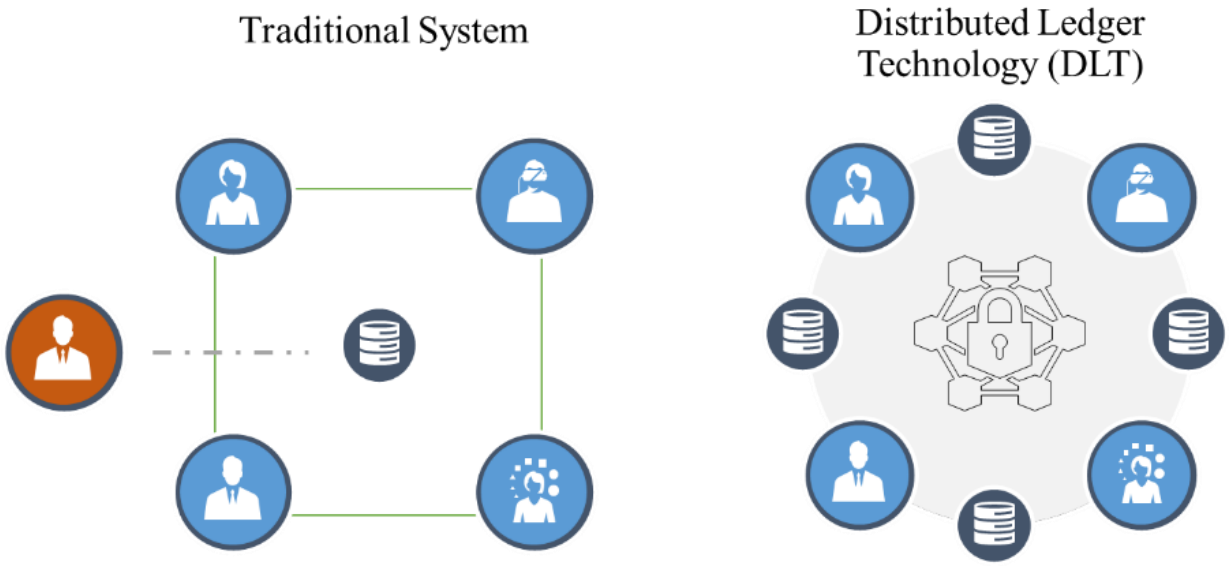


Figure 1. , An illustration for the difference between traditional systems and DLT based systems

Blockchain from a design perspective?

For the purpose of highlighting the potential of Blockchain adoption in construction, specifically with BIM implementations, the main Blockchain components are:

A Distributed Ledger

It is the distributed records of all transactions on a Blockchain, it is a one way append-only record secured by cryptographic algorithms that guarantee that once recorded it is never modified (HyperledgerDocs, 2018). A ledger can be public (permission less) with no central ownership and can be viewed and accessed by any public member, while a private (permissioned) ledger is only accessed by already defined participants who are authorized by cryptographic keys (WANG et al., 2017).

Smart Contracts

Are coded instructions that are automatically executed according to the fulfillment of specific condition (Mathews, Bowe and Robles, 2017). They provide controlled access and consistent update to the Blockchain Ledger, to enable ledger functions like (transacting, querying, etc) (HyperledgerDocs, 2018), they can be considered as "set of promises" (Jerry I-H Hsiao, 2017) as once they got deployed on a ledger, they automatically enforce accountability and remove the need for a human involvement.

Consensus

It is the key principle for agreement, the ledger will not record a transaction unless approved by the proper participant, then all ledgers on all distributed will append the same transactions in the same order (HyperledgerDocs, 2018).

Peers

Peers represents organizations (Yang et al., 2020) their roles are to execute a transaction proposal, validate transactions. Each Peer has a copy of the smart contracts and the immutable ledger (HyperledgerDocs, 2018).

What is BIM

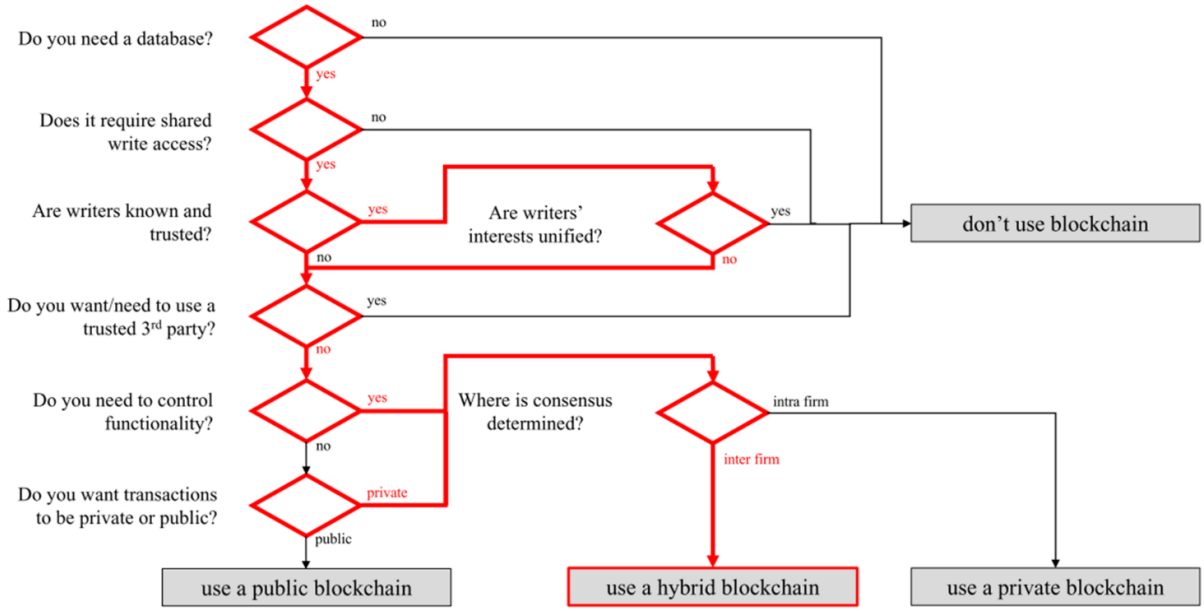
Among all the definitions and references for BIM, and for the purpose of this paper, stating that "With BIM, you design with objects, not lines, arcs, and shapes" (Autodesk, 2015) could be of the best interest, the word "objects" represents everything of any size or magnitude varying from a small window or door to even a complex Jet Engine.

Why Blockchain in Construction and Why with BIM

Bridging the gap between Blockchain and Construction industry relies on certain principles,

(Greenspan, 2015) suggested eight main principles to identify whether the usage of Blockchain for certain business case is viable or not, which are the need for centralized database, presence of multiple writers, no trust among writers, the need to eliminate 3rd parties, functionality control, rules setting, need for validators, and the presence of an asset to be tracked.

(Turk and Klinc, 2017) used these principles to draw a decision chart (Figure 2) to confirm that building projects have the typical needs for collaboration, types of transactions and also the need for responsibility and accountability management that make the use of Blockchain ideal for the industry.



BIM aims at exchanging information digitally, creating a single source for data originally created and shared by stakeholders during the construction phases (Di Giuda et al., 2020). Transactions in building projects and the legal effects resulting from failures are typical cases to apply Blockchain as the stakeholders are already known, it is not guaranteed that they completely trust each other, data writers' interest are not unified, third parties are not preferred and the functionality control is required as it is defined by the stakeholders, all transaction must be within the transacting parties and finally, consensus is defined between stakeholders (Turk and Klinc, 2017).

Why Permissioned Blockchain

Adding to the decision chart in Figure 1, a typical construction project of any size have known participants who basically have signed contracts (Nawari and Ravindran, 2019b) , in addition, Public Blockchains (Permission-less) lack the privacy as all participants have visibility to all transactions data, and also lack centralized management which places the control of the consensus to the Blockchain protocol and this is against the nature of the industry, unless the use case requires public consensus like Intellectual Property use cases.

BIM and Blockchain

Blockchain from its definition has no update or delete in it, this nature enabled other capabilities in the construction industry from transparency, traceability and collaboration (Balint Penzes, 2018). This section highlights on the Blockchain potential with BIM from the angel of these three features along with the interoperability between BIM and Blockchain.

Interoperability

On the model information level, using Industry Foundation Classes (IFC) BIM and Blockchain can be mapped, (Xue and Lu, 2020) used IFC semantics to introduce an approach to minimize information redundancy of BIM changes over time, mapping BIM onto Blockchain, as in Figure 3.

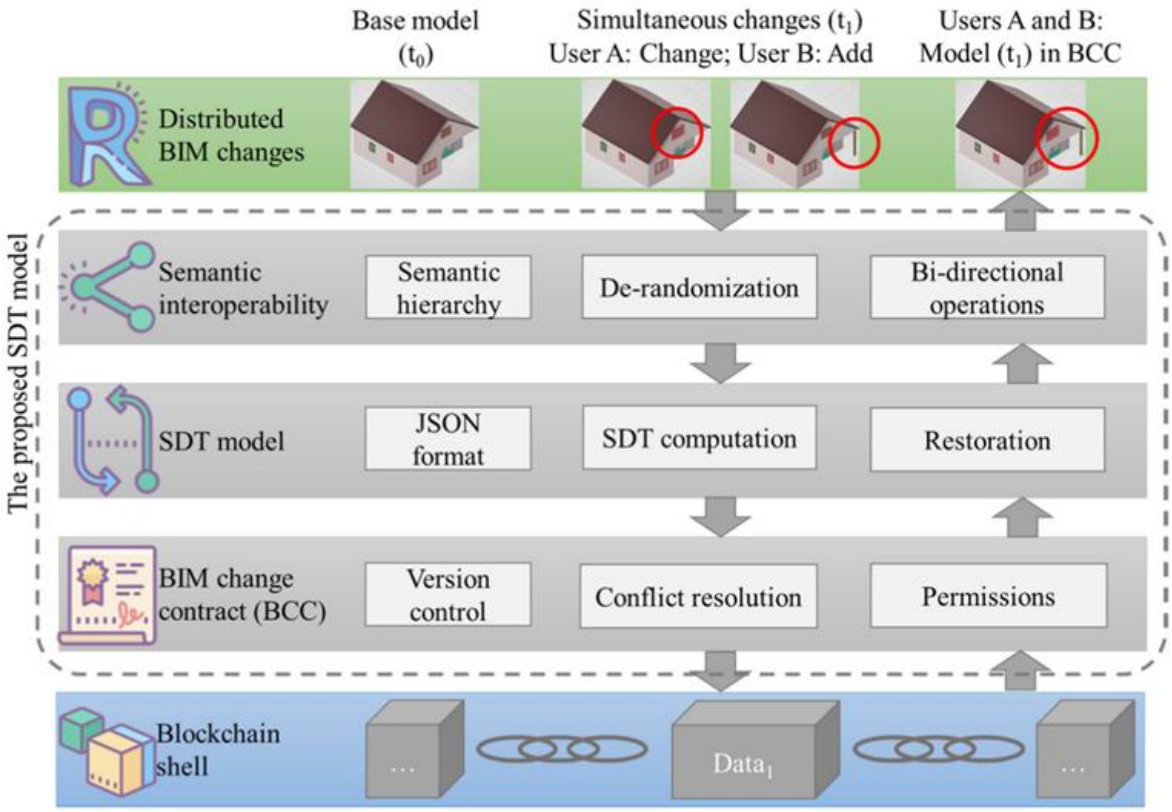


Figure 3. Integrating BIM and Blockchain using IFC semantic interoperability (Xue and Lu, 2020)

From BIM process perspective, having the employer requirement as the center of attention is very essential, and this is why project's requirements and its information delivery milestones must be governed. In their research, (Raslan et al., 2020) proposed a framework to use Blockchain smart contracts to match the Employer Information Requirements (EIR) with what the suppliers and contractors needs to comply with, creating a Blockchain structure to store graphical models, non-graphical information and links to documentation, matching them all to the Asset Information Model (AIM).

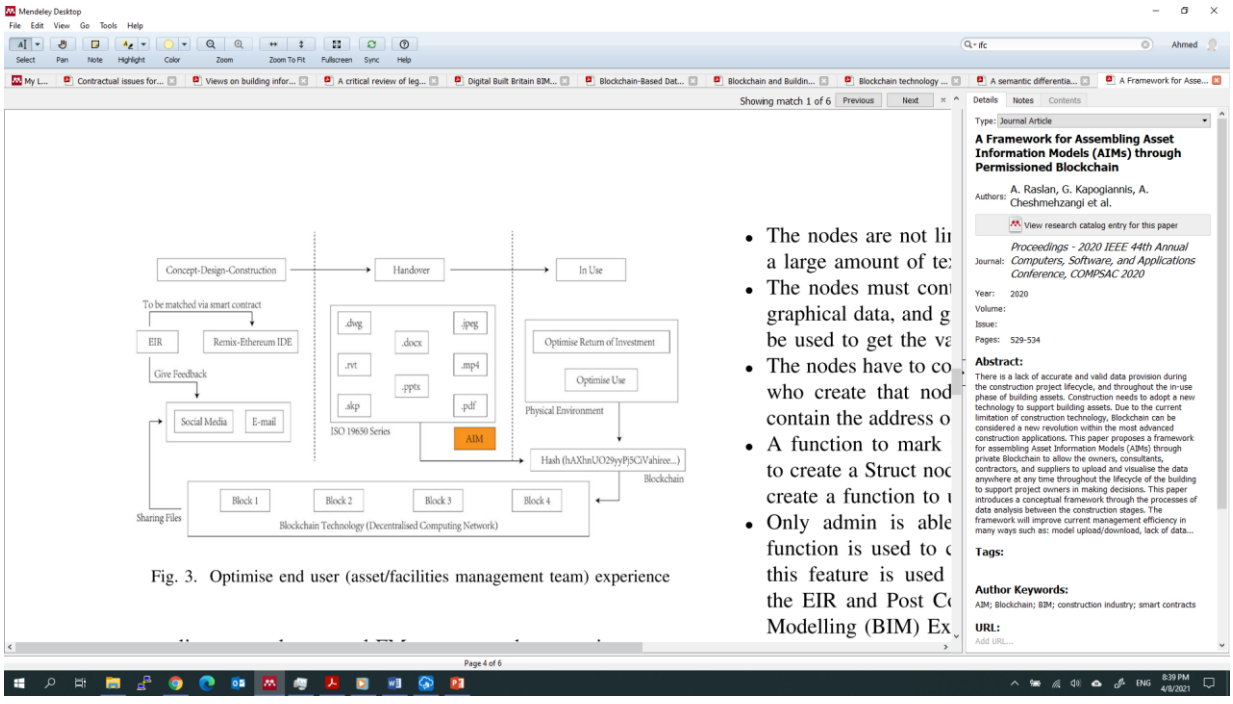


Figure 4. Optimizing Asset & Facilities Management team experience (Raslan et al., 2020)

There is an interesting correlation between Blockchain and AIM and BIM which gives a potential for each technology to fill each other's gap (Raslan et al., 2020).

BIM also can encapsulate Blockchain verified supply chain information, material tracking records or payment information (Balint Penzes, 2018), it can also give back model changes information and approvals. Also making use of Blockchain smart contracts, payments can be initiated based on other Blockchain triggers like inspection completion for specific activities (Moreira, Mota and Machado, 2021).

Transparency

With its immutable record keeping capability, all records are written according to a predefined and agreed upon consensus mechanism between participants, (Nawari and Ravindran, 2019b) stated that DLT's transparency along with BIM properties can present an 'proof of trust', which would make another incentive for the AEC business. As an example for transparency, In their research, (Nawari and Ravindran, 2019b) introduced a Blockchain+BIM framework for compliance and code-check automation of the review and submission of construction permits.

Traceability (Provenance)

There is a major data loss problem in the construction industry (Branner, 2017) as 95% of data is either thrown out or not even collected. Provenance is one of the capabilities of Blockchain as it is a byproduct of its immutability, responsibility and accountability can be spotted, and also future risk can be anticipated if we can know where the error came from or who caused it (Xue and Lu, 2020). In their paper, (Xue and Lu, 2020) referred to what they called "Recent construction scandals", like the false results of testing "Hong Kong-Zhuhai-Macau bridge" or the improper construction in "Hung Hom MTR Station", adding that Blockchain could've been the safeguard of building information provenance for forensic investigation purposes.

Although provenance or traceability indicate a backward notion, the forward look is also important as most construction activities don't just stop at the as-built state, they continue operation until decommission of the asset or coming to the end of its life cycle (Balint Penzes, 2018). In principle, using COBie approach, the delivery of model information within BIM framework is a must from the start of any construction project and can provide the necessary basis for operation and maintenance stages, and (Balint Penzes, 2018) called it a "Blockchain empowered Digital Twin" that enables Smart Asset Management lifecycle.

Blockchain can also be a great enabler for construction supply chain (Wang et al., 2020), as in their study, precast information is saved on the distributed ledger for the access of only predefined participants, also anticipating execution disturbance in advance and controlling the schedule in real-time can be achieved since all timestamps for each process can be retrieved by participants and all information details on the precast operation is stored and automatically updated.

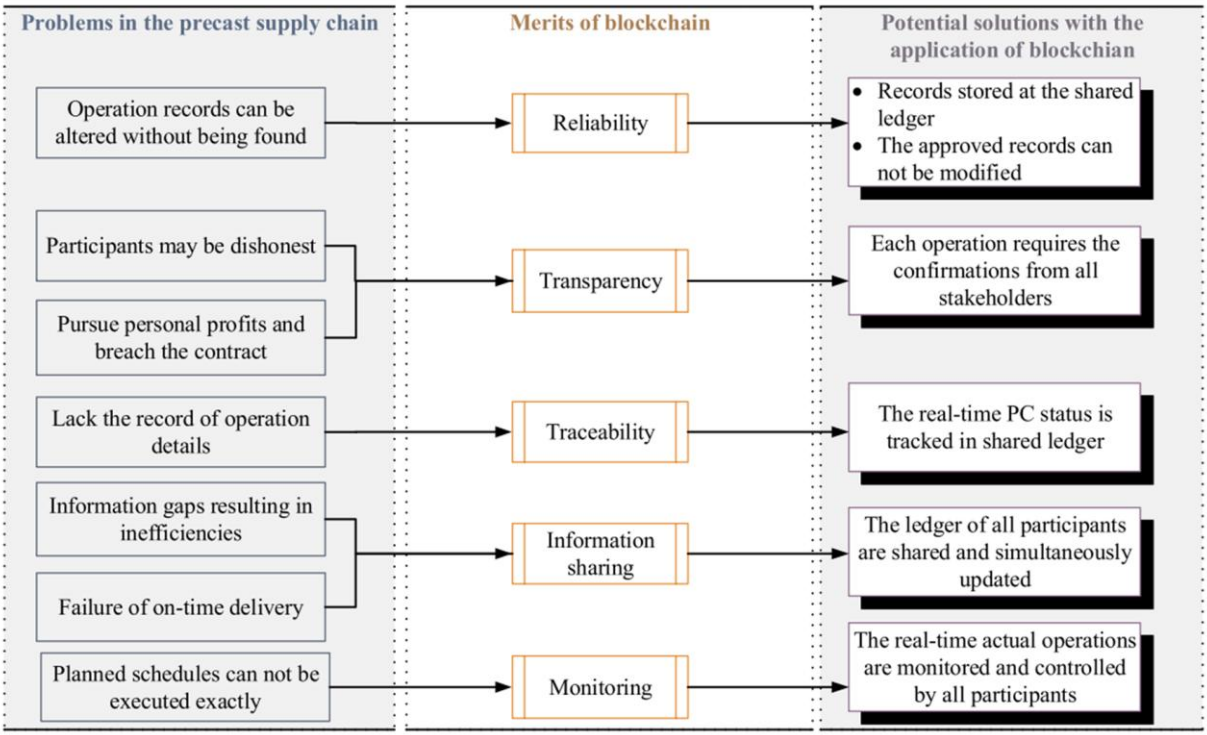


Figure 5. Blockchain Capabilities as a solution for problems in a precast supply chain.(Wang et al., 2020)

Collaboration

Blockchain can make use of other technologies in a way that can drive more efficiencies, culture transformation of the industry (Mathews, Bowe and Robles, 2017), moreover among the other advancements, Blockchain eases the creation of consensus based collaborative environments (Nawari and Ravindran, 2019b) and facilitates verifying digital assets and convert it into real value as a result from reality capturing.

From "Trust" perspectives, "Trust" doesn't occur under conditions of uncertainty and "Confidence" is more of an attitude of assurance which involves predictability (De Filippi, Mannan and Reijers, 2020), the argument brought is that the "confidence" resulted from Blockchain environment indirectly reduces how much "trust" is needed, which also provides Blockchain participants with the feeling of control over their information or facts, they expressed it by "Don't Trust, Verify".

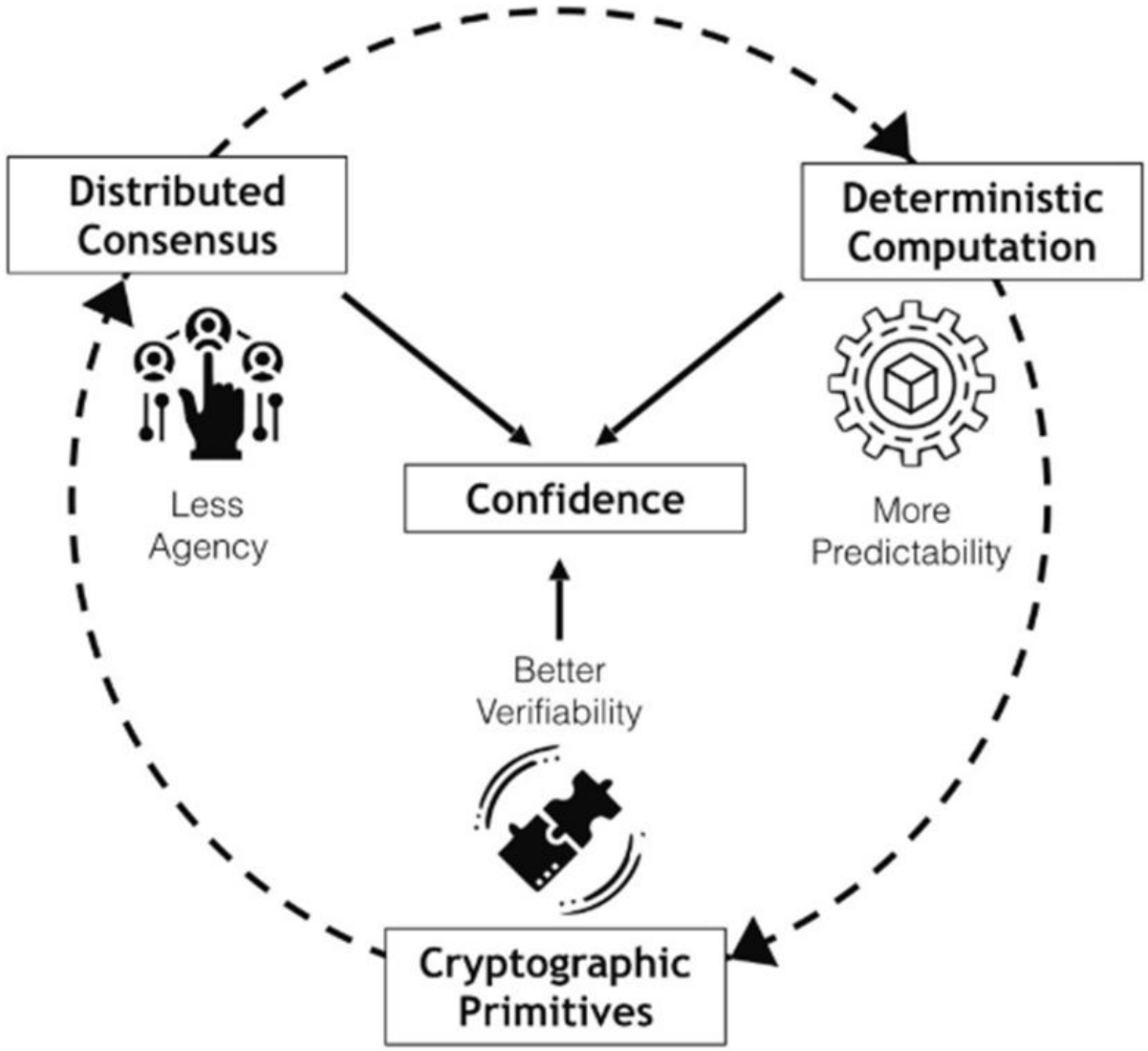


Figure 6. An illustration for Blockchain as a Confidence Machine (De Filippi, Mannan and Reijers, 2020)

Trust is a very important element to promote collaboration among transacting parties (Fan et al., 2018) and Blockchain improves how construction records are trusted, ranging from material quantities inspected to the storage of data generated by sensors (Turk and Klinc, 2017).

Continuing on the collaboration between peers, Blockchain can be used in the controlling Common Pool Resources (CPR) in projects of limited resources (Hunhevicz, 2020) creating an incentive mechanism based on Blockchain tokens.

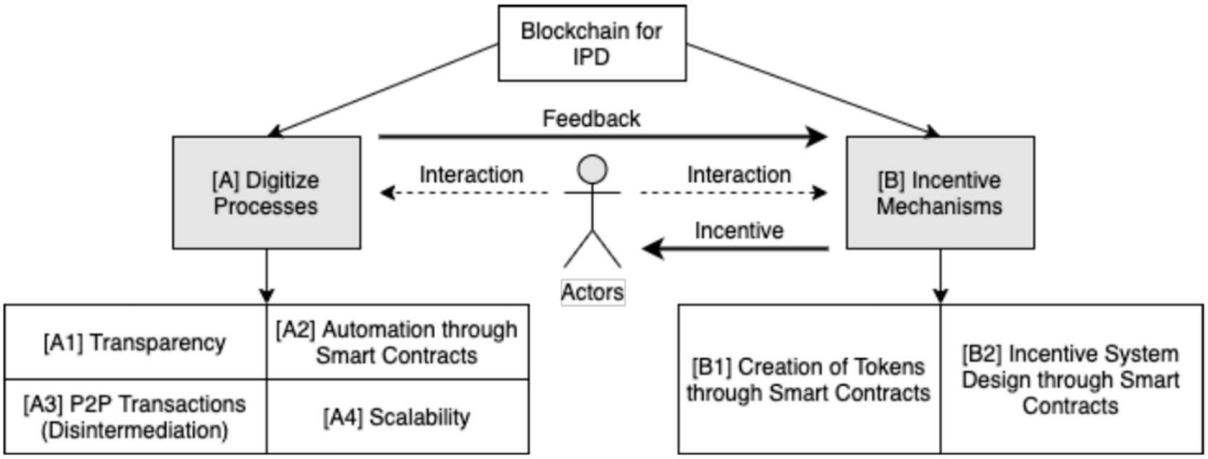


Figure 7. Blockchain can be applied to IPD digitizing processes and incentive mechanisms (Hunhevicz, 2020)

Conclusion

From process perspectives, Blockchain can preserve historical modifications and provide the required level of interoperability between different construction as well as BIM stages, the immutability of Blockchain can provide an incorruptible trace for liabilities responsibilities, event and also preserve IP rights, and smart contracts can also constitute a digitally legal framework relying on the traceability and transparency of the Blockchain ledger.

The conversation between BIM and Blockchain using industry standards like IFC, COBie, AIM..etc, is possible and can lead to significant enhancements in Integrated Project Delivery initiatives and solve BIM challenges from technology, process and legal perspectives. Moreover, as projects data and participants increases going through construction phases, Blockchain can provide the necessary means of trust that foster collaboration among stakeholders, which is a key for BIM Maturity and can be an enabler for BIM Maturity Level 3. Blockchain can also play a vital role in managing data from distributed sensors can enhance the whole IoT usage with filling its gaps and shortages capitalizing on its potential (Casino, Dasaklis and Patsakis, 2019). And the intersection between Blockchain, BIM, IoT and other technologies can be of a systemic change in the AECOO industry (Mathews, Bowe and Robles, 2017). Finally, Blockchain has the potential to enable other technologies and strategies shifting the governance and trust to more digitally governed arena.

Figures

Figure 1. , An illustration for the difference between traditional systems and DLT based systems2

Figure 2. , A decision tree to determine the type of Blockchain to use. (Turk and Klinc, 2017)3

Figure 3. Integrating BIM and Blockchain using IFC semantic interoperability (Xue and Lu, 2020)4

Figure 4. Optimizing Asset & Facilities Management team experience (Raslan et al., 2020)5

Figure 5. Blockchain Capabilities as a solution for problems in a precast supply chain.(Wang et al., 2020)6

Figure 6. An illustration for Blockchain as a Confidence Machine (De Filippi, Mannan and Reijers, 2020)7

Figure 7. Blockchain can be applied to IPD digitizing processes and incentive mechanisms (Hunhevicz, 2020)7

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