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# Blockchain in Architecture

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## ABSTRACT

Blockchain is a decentralized system that uses a peer-to-peer network to create a digital ledger of transactions. It is a decentralized ledger with a growing list of transaction records. It is a promising general-purpose technology that can affect an entire economy and transform both our everyday lives and the ways we do business. It can simplify and secure transactions among parties and record keeping in general. Architects can utilize blockchain technology to enhance the transparency, security, and efficiency of their design and construction process by creating a decentralized and immutable record of project data. The aim of this paper is to explore the use of blockchain technology in architecture.

***KEYWORDS:*** *blockchain, distributed digital ledger, architecture, architecture industry*

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## INTRODUCTION

Blockchain is a technology that allows the recording of information in a way that it is difficult or practically impossible to alter, hack, or cheat. It is regarded as a promising general-purpose technology (GPT) in that it has the potential to affect an entire economy, impacting economic growth and transforming both everyday life and the ways in which we conduct business. Given its unique characteristics, such as immutability, transparency, decentralization, and distribution, blockchain is recognized by many as a new form of GPT. The symbol of a blockchain is depicted in Figure 1 [1].

Construction is one of the largest industries in the world, creating infrastructure which is the backbone of productivity and economic growth. The architecture, engineering, and construction (AEC) industry has entered a period of major disruption caused by a host of emerging digital technologies such as artificial intelligence (AI), the Internet of things (IoT), virtual reality (VR), augmented reality (AR), building information modelling (BIM), 3D printing, robotics, drones, big data, and others. Lately, another innovative digital technology, blockchain, has appeared, promising to change the way people do transactions, keep records, validate data, and much more. Blockchain is a new general-purpose technology that can transform both our everyday lives and the ways we do business [2].

## WHAT IS BLOCKCHAIN?

Blockchain, a type of distributed digital ledger technology (DLT), is a relatively new and exciting way of recording transactions in the digital age. It is a decentralized and distributed digital ledger technology that securely records and verifies transactions across multiple computers or nodes in a network. Basically, it is a chain of blocks in which each block contains a list of transactions. The blockchain technology was created as the foundational basis for Bitcoin – a digital currency in which secure peer-to-peer transactions occur over the Internet. It is expected that the spending on blockchain solutions worldwide would grow from 4.5 billion USD (2020) to an estimated value of 19 billion USD by 2024 [3].

Originally developed as the accounting method for the virtual currency Bitcoin, Blockchains are

appearing in a variety of commercial applications today. Blockchain technology is a type of distributed digital ledger that uses encryption to make entries permanent and tamper-proof and can be programmed to record financial transactions. It is used for secure transfer of money, assets, and information via a computer network such as the Internet without requiring a third-party intermediary. It is now being adopted across financial and non-financial sectors. As a catalyst for change, the Blockchain technology is going to change the business world and financial matters in major ways.

The first Blockchain was conceived in 2008 by an anonymous person or group known as Satoshi Nakamoto, who published a white paper introducing the concept of a peer-to-peer electronic cash system he called Bitcoin [4,5]. Bitcoin and Ethereum are the first two mainstream blockchains. Other modern blockchains include Namecoin, Peercoin, Ether, and Litecoin. Figure 2 shows different components of blockchain [6].

Blockchain combines existing technologies such as distributed digital ledgers, encryption, immutable records management, asset tokenization and decentralized governance to capture and record information that participants in a network need to interact and transact. As illustrated in Figure 3, a complete blockchain incorporates all the following five elements [7]:

- *Distribution:* Digital assets are distributed, not copied or transferred. A protocol establishes a set of rules in the form of distributed mathematical computations that ensures the integrity of the data exchanged among a large number of computing devises without going though a trusted third party. A centralized architecture presents several issues including a single point of failure and problems of scalability.
- *Encryption:* BC uses technologies such as public and private keys to record data securely and semi-anonymously. Completed transactions are cryptographically signed, time-stamped, and sequentially added to the ledger.
- *Immutability:* The blockchain was designed so these transactions are immutable, i.e. they cannot be deleted. No entity can modify the transaction records. Thus, Blockchains are secure and meddle-free by design. Data can be distributed, but not copied.
- *Tokenization:* Value is exchanged in the form of tokens, which can represent a wide variety of asset types, including monetary assets, units of data or user identities.
- *Decentralization*: No single entity controls a majority of the nodes or dictates the rules. A consensus mechanism verifies and approves transactions, eliminating the need for a central intermediary to govern the network.

Bitcoin and its underlying blockchain technology increasingly impact all facets of society. Bitcoin's status as digital gold is merely the tip of this technology. Figure 4 shows Bitcoin [8], while Figure 5 shows how blockchain works [9]. Although blockchain technology will for all time be associated with Bitcoin due to their common genesis, it has broader applications. Cryptocurrency will increasingly become a factor in family law issues as well.

A blockchain is a tamper-proof, distributed database that stores blocks of information for cryptographically bound transactions via peer-to-peer networks. At the heart of blockchain's functionality is cryptographic hashing. Each block in a blockchain contains a cryptographic hash of the previous block, creating an immutable chain of blocks. If anyone attempts to tamper with the data in a block, it would alter the block's hash. This would disrupt the entire chain, making it virtually impossible to manipulate. The security feature ensures data integrity and prevents unauthorized changes [10].

In a nutshell, blockchain technology involves three basic concepts [11]: (1) It is a system for recording a series of data items (such as transactions between parties); (2) It uses cryptography to make it difficult to tamper with past entries; (3) It has an agreed process for storing copies of the ledger and adding new entries (also called a consensus protocol).

Blockchain is a novel decentralized infrastructure and distributed computing paradigm that uses a chained data structure for verification, storage, and distributed consensus algorithms to generate and update data. Decentralization is a key feature of blockchain technology, which refers to the distribution of power and decision-making across a network of nodes or participants rather than being controlled by a central authority or system. It provides robustness while eliminating many-to-one traffic flows to avoid delays and single points of failure. Figure 6 shows the decentralized property of blockchain [9]. The advantages of decentralized property of blockchain network include the following [9]:

- The decentralized property of blockchain makes it less prone to failure and more expensive for hackers to attack the network.
- There is no third-party involvement; therefore, there is no added risk.

- Every change made in the network is traceable and concrete.
- Users maintain full autonomy of their properties and are not dependent on third parties to maintain and manage their assets.
- It provides enhanced security.

## BLOCKCHAIN IN ARCHITECTURE

Blockchain technology can be used in architecture to improve the design process, increase efficiency, and enhance transparency. It has the potential of addressing common problems of the AEC industry, while it can be adaptable to the construction/architecture industry structure and the way it is practiced. Blockchain's immutability ensures that once data is recorded, it cannot be altered or tampered with. This feature can be beneficial for maintaining a secure and unalterable record of design iterations, decisions, and project milestones, providing a transparent audit trail throughout the design process. Blockchain technology can enhance the architectural design process by providing immutable records, smart contracts, improved supply chain management, and decentralized collaboration. It promotes transparency, efficiency, and better project outcomes.

## APPLICATIONS OF BLOCKCHAIN IN ARCHITECTURE

In this section we identify several key areas of the civil, architectural, and construction industry where blockchain can be applied. Blockchain technology has many uses in architecture, including data management, collaboration, and contract creation. We identify five relevant areas of benefit, namely: (1) supply chain management, (2) building information modelling (BIM), (3) contract management, (4) project management, (5) smart cities, (6) real estate. These common applications are explained as follows [2]:

- *Supply Chain Management*: The construction industry is characterized by fragmentation in processes, operations, and services. One of its major problems is the disconnect between construction and design, due to the lack of trustworthy and open information across the supply chain. Blockchain has the potential to adverse these issues using open and transparent transactions. It can improve payment settlements, compliance management and material planning, while smart contracts can be implemented to automatically purchase, track, and verify items in the supply chain, in real-time.
- *Building Information Modelling:* BIM is a digital representation of physical and functional characteristics of a facility. It is known as the cutting-edge technology for use in AEC practices. It is a crucial part of promoting the effectiveness of project collaboration throughout the whole building lifecycle. Blockchain can be used to provide live and trustworthy information for BIM, by information sharing among present and future information owners. It can help enhance the benefits of BIM by allowing architects and engineers to design on the same BIM model with clear ownership, while design and construction decisions can be recorded on the blockchain for future analysis and liability. With BIM-blockchain integration, the AEC industry can avoid various issues and get several benefits. Figure 7 shows BIM in the architecture industry [12].
- *Contract Management and Smart Contracts:* A smart contract is a computer program that works based on an "if/then" principle. Smart contracts are executed automatically reducing the necessity of intermediaries and as a result time and money can be saved. Blockchain can be used to create project-specific contracts that are restricted to certified contractors. A blockchain-based contract can be created for a project, restricted to certified contractors, and voided if certain requirements are not met. Smart contracts on blockchain can automate contract execution based on pre-defined conditions, simplifying complex agreements between stakeholders and reducing administrative overhead. Decentralized smart contracts based on blockchain can address some limitations in an effective way. Smart contracts are used in smart buildings for repairs and service. Figure 8 shows smart contracts [13].
- *Project Management:* Construction project management (CPM) can potentially benefit from an agile and more decentralized approach based on blockchain, with high transparency. Blockchain has a credible potential in the construction industry, due to its exponential general use, the investments involved, and a number of start-up businesses contributing to Industry 4.0. A blockchain-based CPM platform implementing smart contract technologies facilitates the peer-to-peer collaboration between parties in the construction industry, leading to improved information flow, cost, and time reduction, and improvement in the quality of the services.
- *Smart Cities:* As urbanization is increasing rapidly, offering improved livability and a higher standard of living, the concept of "smart cities" is

one of the main focus areas of many governments across the globe. Smart cities enable operational efficiency, maximize environmental sustainability efforts, and create new citizen services. Blockchain innovation can be utilized to make smarter cities. Blockchain-based solutions can be utilized to enhance our cities and provide for better economic development and livability, by offering enhanced security, immutability, resilience and transparency. Blockchain and smart contracts can securely and flexibly manage building access privileges for both short-term visitors and long-term occupants, taking into consideration the risk associated with accessing a space in the building, in an efficient, decentralized way. For example, the Smart Dubai initiative aims to use blockchain technology to transform the city into a smart and sustainable hub, by streamlining the processes and transactions of various sectors, including architecture and construction. As another example, cryptocurrency millionaire Jeffrey Berns has revealed plans to develop a large parcel of Nevada's desert into a smart city powered by blockchain technology. He intends to use the smart city as a new kind of business and residential community, with a decentralized blockchain infrastructure underlying all interaction. Such a planned smart city powered by blockchain is shown Figure 9 [14]. A potential major advantage of this city model is greater control of privacy of personal information.

- *Real Estate:* Real estate is known as one of the most important sectors of the economy, playing a crucial role in the lives of people across the world. Real estate investments provide better returns than the stock market without as much volatility, providing also tax benefits in many cases. Real estate is still a "pen and pencil" business, relying on archaic methods for keeping records and doing transactions. Figure 10 presents the real estate ecosystem [2] today and depicts the number of different parties involved and the relevant interactions. This traditional model has several drawbacks and limitations. There are a lot of intermediaries, that increase the cost and reduce the transactions' speed. Real estate is entering the blockchain era and it can benefit from the numerous advantages that the technology can offer. With Blockchain, all real estate ownership and transaction records can be stored securely as tamper-proof digital records on the blockchain, in a decentralized way.

**BENEFITS**

Blockchain technology can offer several benefits for the design process in architecture. Blockchain's decentralized and transparent nature can help improve the efficiency and security of the design process and can also help with collaboration and communication. Blockchain technology has the potential to enhance various aspects of the design process for architects by providing transparency, security, and efficiency. The five greatest advantages of blockchain technology in industries are higher transparency, higher security, higher traceability, higher efficiency and speed, and lower costs. Other benefits of blockchain in architecture include the following [15,16]:

- *Decentralization*: Architects often deal with large volumes of data, including design plans, specifications, and project documentation. Blockchain's decentralized nature allows for secure storage and sharing of data without reliance on a central authority. Centralization can undermine the technology's purpose as a shared ledger. Too much power can be placed in the control of a single entity or a few special "players." When a single entity takes too much power then it may no longer operate for the benefit of the society. Fully decentralized distributed systems can mitigate risk and prevent attacks while centralized systems are more prone to them.
- *Increased Transparency:* BC can enhance the transparency and trust of the design process, as it provides a secure and immutable record of the project history, decisions, and changes. It can increase the efficiency of processes within the construction industry and eliminate current issues related to trust, verification and transparency. It can create a secure and immutable record of project history, decisions, and changes. All project data is readily accessible and verifiable by all parties involved, reducing the risk of fraud or manipulation.
- *Enhanced Efficiency:* BC can increase the efficiency and accuracy of data management, as it eliminates the need for manual entry, duplication, and reconciliation of information. Streamlined workflows and automated processes can significantly reduce administrative burdens and accelerate project timelines. The AEC industry needs to complete the task much faster than possible with a single computer. It is essential to meet this need by adopting distributed ledger technologies (DLT).

- *Smart Contracts:* Smart contracts, self-executing contracts with the terms of the agreement directly written into code, can automate and enforce various aspects of project management. This includes automatically triggering payments, managing project milestones, and ensuring that contractual obligations are met, streamlining administrative processes.
- *Collaboration:* Blockchain technology can enhance the architectural design process by providing immutable records, smart contracts, improved supply chain management, and decentralized collaboration. Blockchain can facilitate the collaboration and communication of the design team, as it enables real-time sharing and verification of data, documents, and contracts. It allows design teams to share and verify data, documents, and contracts in real time. A shared blockchain platform can enable real-time data sharing between architects, engineers, contractors, and clients, fostering better communication and coordination.
- *Secure Storage:* Conventional cloud storage and computing in building information modeling (BIM) are ineffective in providing trusted networks. Nowadays, the need for distributed storage and computing has been highlighted by the AEC industry. Blockchain's decentralized nature allows for secure storage of large amounts of data, such as design plans and specifications. Traditional cloud computing environment has a data center that contains many computers. One major issue in such centralized storage and computing concerns the risk of operating failure. Trusted networks are urgently needed for data storage and computing. Applying distributed storage and computing can essentially reduce the risk of failure and provide trusted networks.
- *Clash detection:* Digital tools based on BIM provide automatic quantity take-off and clash detection. Such BIM technology has been widely applied in clash management that includes clash detection and resolution during design coordination of buildings and infrastructures. Generally, BIM coordinators conduct clash detection by merging architectural, structural, and mechanical, electrical, and plumbing (MEP) models in an integrated BIM platform, launching automatic clash detection algorithms, and then generating clash detection reports.
- *Improved Accountability:* Each stakeholder's actions and decisions are clearly recorded on the blockchain, enhancing accountability and responsibility. Blockchain introduces a new level of responsibility in construction. Everyone involved gets access to the same unchangeable data, ensuring each party is held accountable for their actions. It leads to a more honest and responsible way of implementing construction projects.
- *Tracking Design Changes:* Recording every design modification on the blockchain ensures a complete, verifiable history of project evolution, eliminating discrepancies and facilitating easier conflict resolution.
- *Material Traceability*: By recording the origin and provenance of building materials on the blockchain, architects can verify sustainability claims and ensure materials meet quality standards.
- *Reduced Costs:* By minimizing errors and disputes, blockchain can potentially lead to cost savings throughout the construction process

## CHALLENGES

Blockchain technology poses some challenges for the design process in architecture. Like the Internet in its first years, blockchain is difficult to predict or even understand well. Information exchange in BIM is critical yet complex due to the multi-party collaboration nature of a construction project. Other challenges include the following [15,16]:

- *Resistance to Change:* The construction industry has traditionally been very reluctant to change and rather slow in adopting new digitization technologies. It can be difficult to persuade stakeholders to invest in this technology, particularly if they are used to conventional approaches. It is essential to show the long-term advantages and return on investment in order to get over change resistance.
- *Data Privacy and Security:* In a world where massive data is generated daily, data privacy has become a major concern. Blockchain goes a long way in addressing this issue. Given that the construction business deals with sensitive information and intellectual property, data privacy and security are major issues. Sensitive data is used in construction projects, such as confidential financial information and private designs. Blockchain technology enhances security through encryption and decentralization, but businesses must still take into account the privacy implications and make sure they are in compliance with all applicable laws.
- *Standardization:* For best practices to be established across the sector and to encourage

wider adoption, collaboration, and standardization efforts are essential. Standardization promotes widespread usage of blockchain technology in the construction industry and facilitates frictionless data interchange while increasing transparency. To create industry-wide standards, protocols, and governance models, coordination is required between architectural businesses, technology providers, and regulatory organizations.

- *Scalability:* One of the main challenges is the scalability and performance of the system, as it requires a large amount of computing power and storage capacity to process and store the data.
- *Interoperability:* Another challenge is the interoperability and compatibility of the system, as it requires a common standard and protocol to exchange and integrate data across different platforms and applications.
- *Regulation:* Another challenge is the regulation and governance of the system, as it requires a clear and consistent legal framework and ethical guidelines to protect the rights and responsibilities of the stakeholders.
- *Cyberattacks*: It was observed that the construction industry was the third target of ransomware attacks in North America in 2020. BIM-collaborative design is one of the most vulnerable phases to cyberattacks. Once a malicious insider or an outside attacker performs a successful breach on a single centralized database, the process of recovery can be complex and uncertain.

## CONCLUSION

Blockchain technology is still in its early stages of development and adoption in the design process in architecture. It has the potential to revolutionize the way architects design, communicate, and collaborate. It will play a significant role in architecture industry in the future. In the future, it could become ubiquitous in the exchange of physical and digital goods, record keeping, information, and online platforms. Although blockchain technology is new and there are certainly several early challenges to tackle, it has great potential to become an extremely positive force of change in the architecture industry.

To leverage blockchain technology in architectural design, architects must start by familiarizing themselves with its fundamentals and potential impacts on the industry. By leveraging the power of blockchain technology, architects can improve the quality, efficiency, and innovation of their design solutions, as well as the trust and engagement of their clients and partners. Although nobody can predict the degree to which it will affect the economy, our lives and every single sector including architecture, most experts agree that it has the potential to play a significant role in the future. More information on the integration of blockchain technology into the architecture industry is available from the books in [17-21] and in the following related journals:

- IEEE Blockchain
- Journal of Building Engineering
- Journal of Construction Engineering and Management

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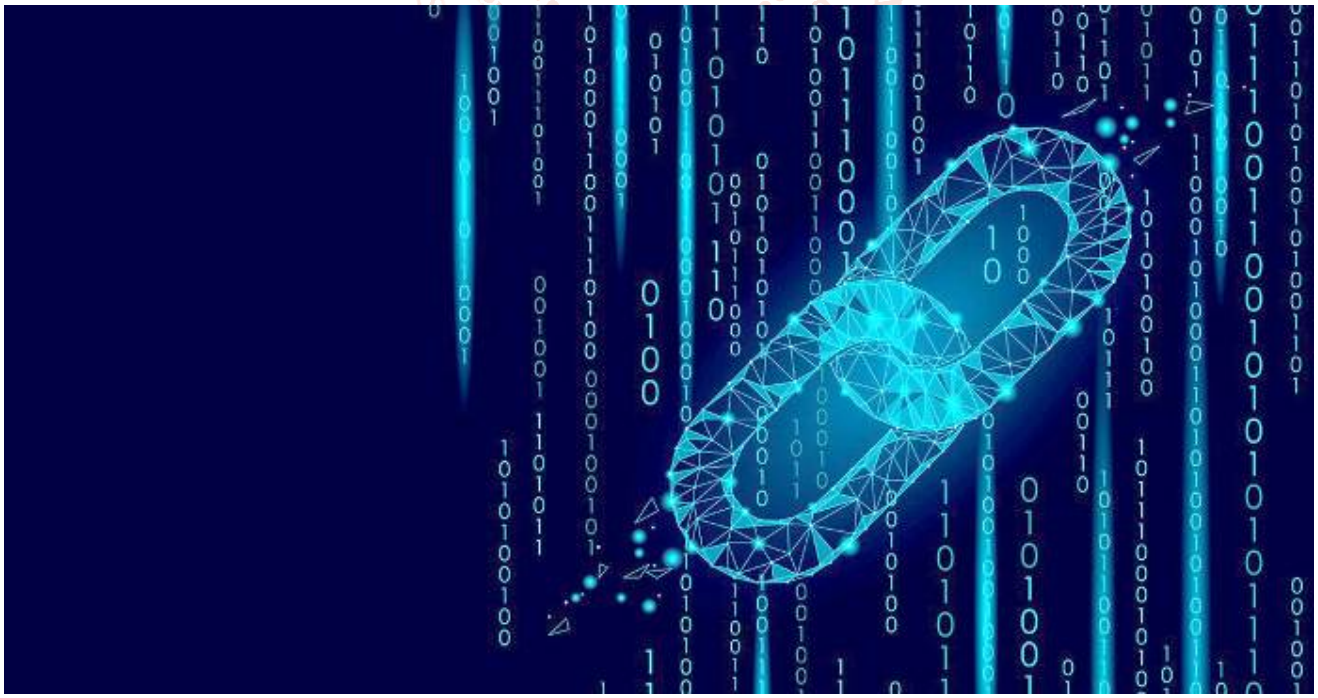

**Figure 1 The symbol of blockchain [1].**

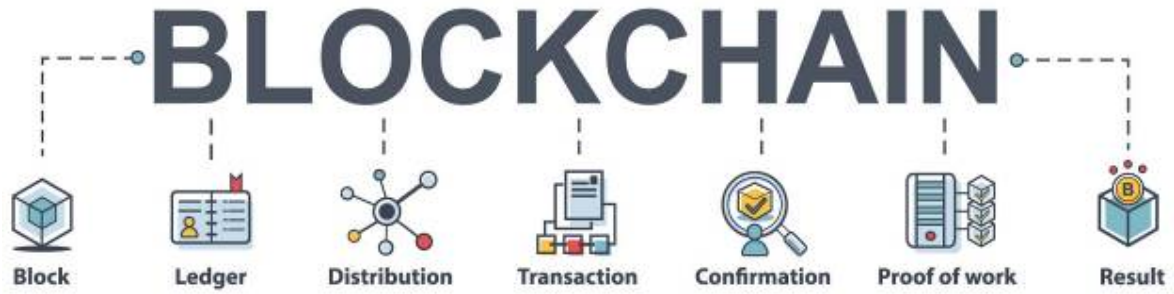


**Figure 2 Different components of blockchain [6].**

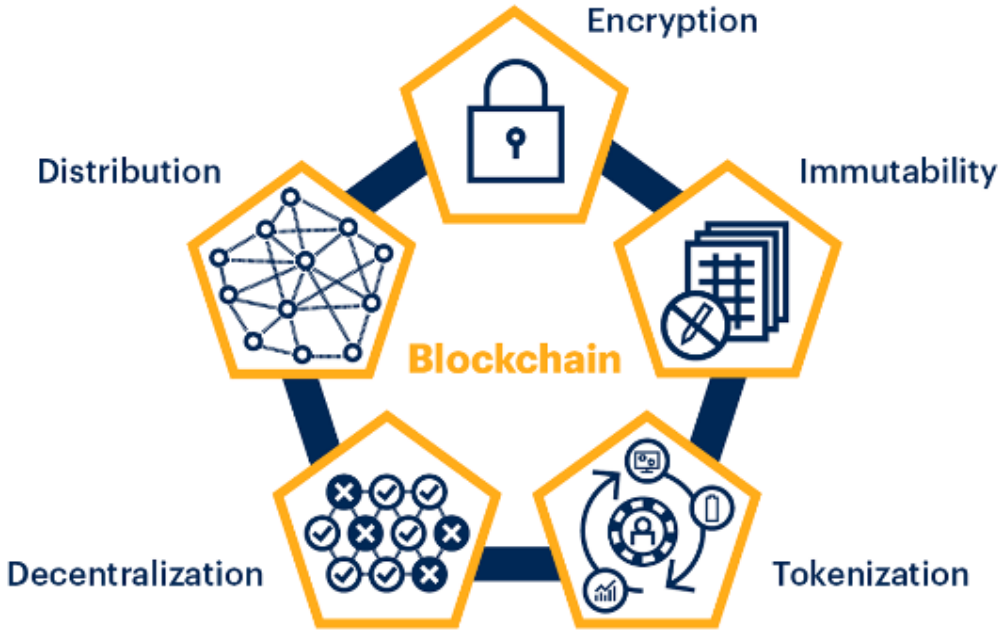


**Figure 3 Five key elements of Blockchain [7].**

**Figure 4 Bitcoin [8].**

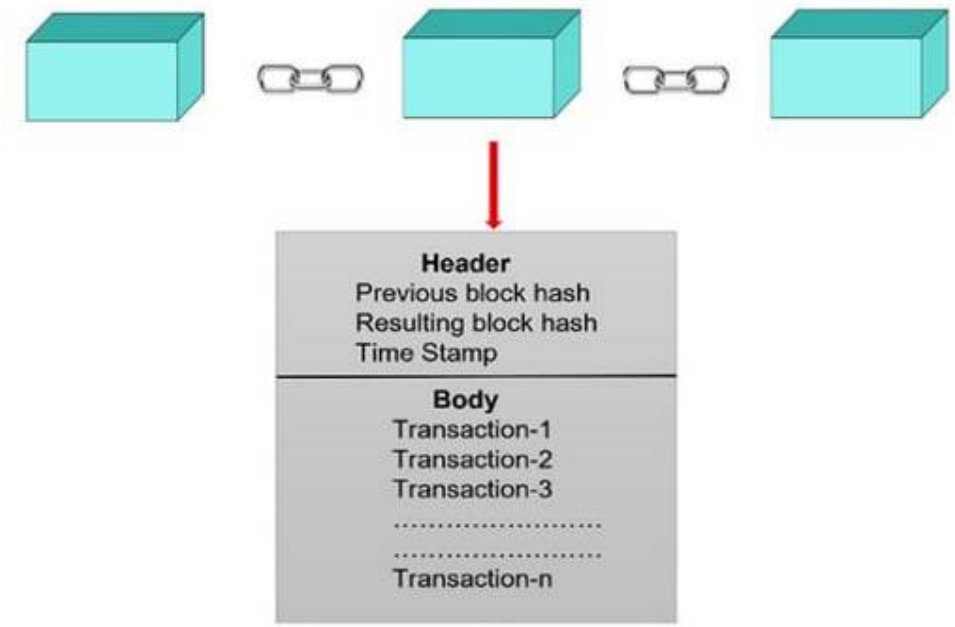


**Figure 5 How blockchain works [9].**

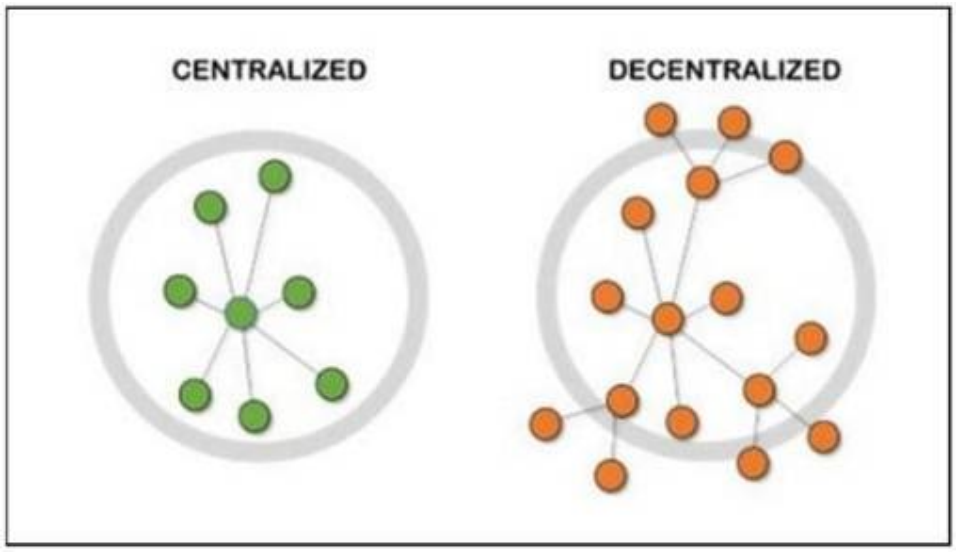


**Figure 6 The decentralized property of blockchain [9].**

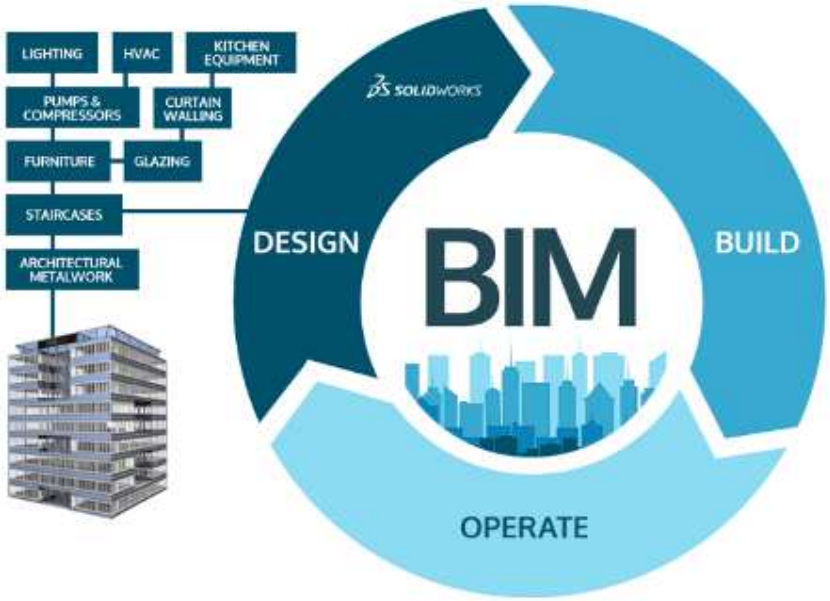


**Figure 7 BIM in the architecture industry [12].**

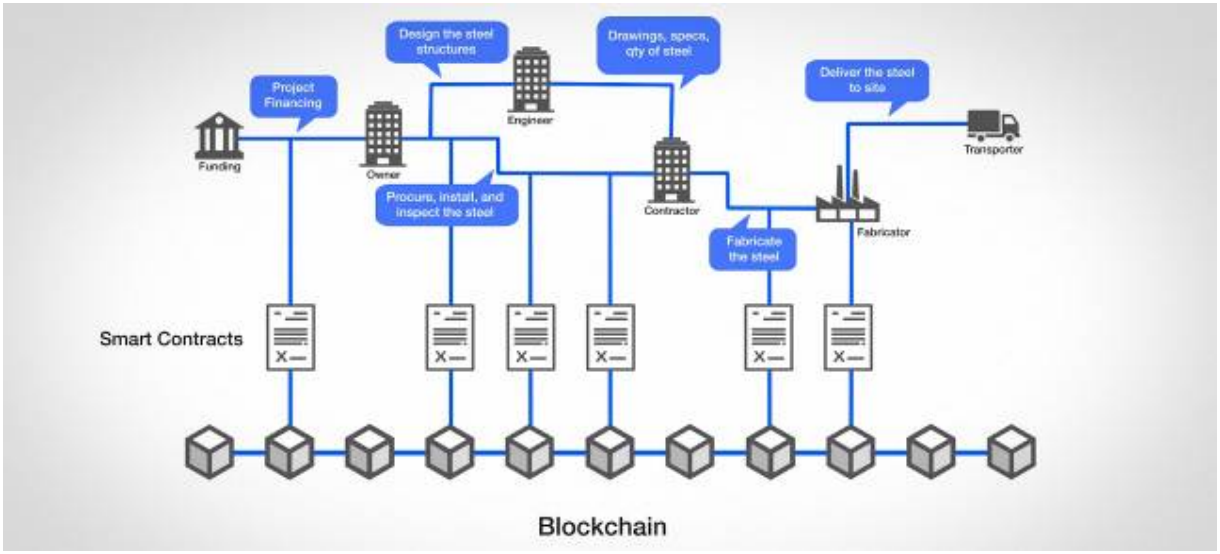


**Figure 8 Smart contracts [13].**

**Figure 9 A planned smart city powered by blockchain [14].**

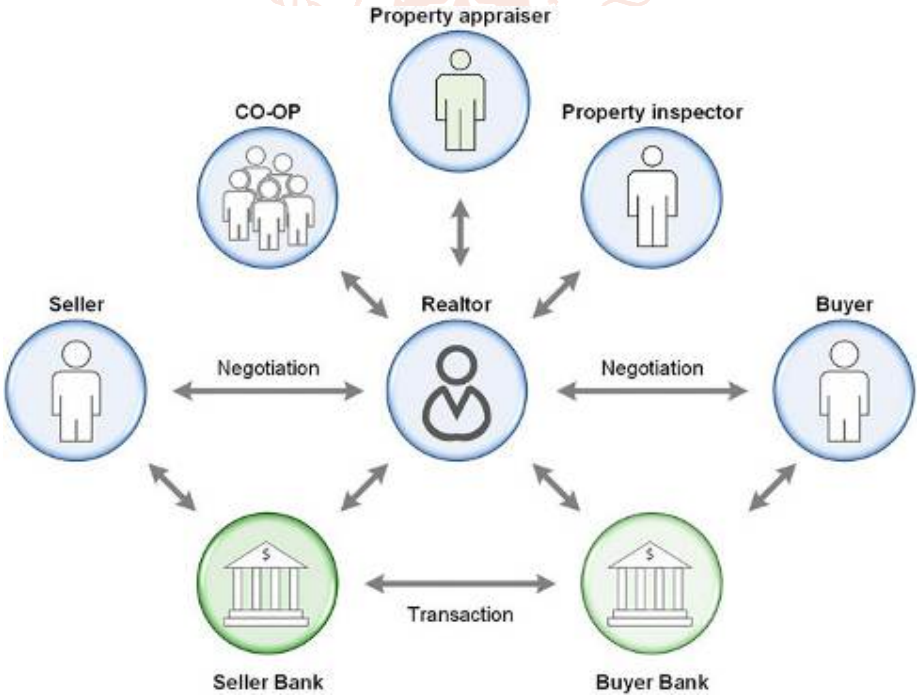


**Figure 10 The real estate ecosystem [2].**